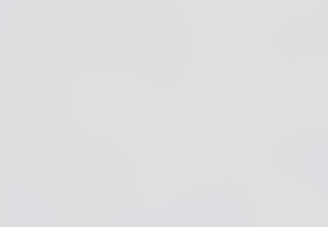




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THE AUTHORS OF THE SEVERAL PAPERS ARE INDIVIDUALLY RESPONSIBLE FOR THE  
SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE  
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ROYAL SOCIETY'S HALL,  
VICTORIA STREET, MELBOURNE, C.A.

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ART. I.—*The Physiographic History of the Victorian Grampians.*

By EDWIN SHERBON HILLS, Ph.D.

[Read 14th May, 1936; issued separately, 23rd November, 1936.]

### Introduction.

The general acceptance by Victorian physiographers of Hart's view, that the Grampian Ranges in Western Victoria owe their topographic form mainly to Tertiary block-faulting, has exercised a profound influence upon interpretations of the physiographic history of other parts of the State. It was chiefly as a result of his studies in the Grampians that Hart himself was led to postulate block-faulting in other sections of the Highlands, and acceptance of the block-faulting idea predisposed physiographers towards invoking faulting in physiographic interpretations, as Fenner admitted in his paper on the Mansfield district (Fenner, 1914, p. 400).

I have recently (1933, 1935) criticised the application of the block-fault hypothesis to the Croydon Lowlands (by Jutson, 1911) and to the Mansfield Basin (by Fenner, 1914), and in this paper I propose to elaborate the view, already presented to an A.N.Z.A.A.S. Excursion in January, 1935, that in the Grampians also, differential erosion of hard and soft rocks, and not Tertiary block-faulting, has been the dominant factor influencing the topographic development.

### General Geology.

The Mt. Difficult, Victoria, Serra (also called Sierra), Dundas, Black and other ranges which together constitute the "Grampians" are composed dominantly of massive quartzose sandstones, with subordinate grits, thin-bedded sandstones (both hard and soft), and sandy shales. It has been suggested that these sediments are Lower Carboniferous (see Chapman, 1916), but the evidence for this is not conclusive. Intrusive into the sediments are sills, dykes and stocks of granodiorite, quartz porphyry, and felspar porphyry (Skeats, 1924), as well as granite, and possibly other igneous rock types not specifically recorded. In the larger valleys there are extensive deposits of alluvium, and the southern part of the Victoria Valley has been invaded by a flow of Newer Basalt.

The general structural relations of the formations present in the Grampians were first referred to by Selwyn (1866), who stated that a syncline exists between the Dundas and Black Ranges in the west, and the Victoria and Sierra Ranges in the





east. Krausé (1874) also mentioned a synclinal structure, the axis of which, he said, appears to run north along the western foot of the Victoria Range to Mount Zero. Gregory (1912, p. 68) described the Grampians as ridges and blocks of old sandstones, in which ridges, folds and faults run north-south. The ridges, he said, are made in part by gentle folds, and in part by faults, but are of the Pennine Type, that is to say, the scarps are erosional features, either fault line scarps or strike ridges (see Avebury, 1906).

Hart, in his paper on the Highlands of Western Victoria (1908), took a different view. He states that the Grampians are to be ascribed to the unequal elevation and tilting of a number of fault blocks, in which the principal faults are approximately meridional, and that the faulting caused a succession of parallel ranges to be formed of the same beds. In support of this he mentions that the earlier geological descriptions give estimates of thickness which are inadequate, unless faulting has occurred, that he had observed a strike fault in Stony Creek, near Hall's Gap, and that, at the Silverband Fall, the stream comes out of a gap in the range and falls to the valley below. As a final qualification, however, he mentions that the faults need not necessarily be altogether of late date, all that is requisite being movement subsequent to the peneplanation, perhaps along old fault lines.

It is solely on the above evidence that the hypothesis of Tertiary block-faulting in the Grampians is based, and Hart's cross section across the Hall's Gap district lends itself to the interpretation later accepted by James (1924, p. 77), that the Grampians are simply fault blocks, in which the escarpments are fault scarps, and the sandstones derive their dip from the tilt of the back slopes of the blocks.

Gregory's remark, that the ranges are of the Pennine Type, has received no subsequent consideration, either critical or appreciative.

### **Topographic Expression in the Grampians.**

The characteristic features, which give to the ranges their topographic expression, are determined in those parts of the Grampians composed of Carboniferous sedimentary rocks by beds of massive resistant sandstones, dipping at different angles in different localities. The erosion of these beds usually results in the development of strike ridges such as the Serra Range, Victoria Range, Mt. Difficult Range, and the Wonderland Range, in which one slope is controlled by the dip (dip slope), and the other (the escarpment) by almost vertical jointing. Where the sandstones dip at high angles, as in the Terraces, a hogback, or if the crest is very sharp, a razorback, results. On the other hand, where the beds are horizontal, or nearly so, erosion results in plateaux with steep bounding escarpments, or in isolated

flat-topped hills such as Tower Hill and Castle Hill in the Victoria Valley, which would be termed in America "buttes".

The granitic country in the Victoria Valley is sharply contrasted topographically with the sandstone ridges, the hills there being smoothly rounded.

The present investigation is concerned, however, with the question of the origin of the major topographic features of the Grampians, rather than with the detailed physiography. Most of the observations were made in the Hall's Gap district, but important information was obtained from other parts, concerning the fundamental importance of differential erosion in the development of the topography.

### **Differential Erosion in the Grampians.**

#### **THE WARTOOK BASIN.**

The Wartook Reservoir is situated in a topographic basin, which occupies the trough of a syncline or elongated tectonic basin (see Fig. 3), and is bounded on the east, north, and west by a continuous ridge of massive sandstones which forms the outer rim of the basin, and dips inwards towards its centre. The continuity of this ridge, and also the synclinal structure which determines the basin, are best seen in the view to the north from Reed's (Chester's) Lookout, in the Mount Victory Range. Krausé has shown the syncline in his section across the north end of the Grampians, mentioning also the fact that the structure is well shown on the north end of the Mount Difficult Range at Rose's Gap, a locality which I was unable to visit.



FIG. 2. View over the basin of the Wartook Reservoir and the Mt. Difficult Range, looking north from Reed's (Chester's) Lookout in the Mt. Victory Range. Note the sandstone ridges dipping inwards towards the synclinal axis, and the continuity of the ridges round the northern end of the basin, due to the southerly pitch of the syncline in the north.

The significance of this excellent example of the structural control of topography, in which the conditions are analogous to those obtaining in parts of the Appalachians, is that, quite clearly,

Tertiary or even older faulting can have played no part in its development, except insofar as the whole of the basin, including its immediate environs, may have been uplifted as part of a large fault block, out of which the features described might then have been dissected by differential erosion. For our present purpose, this possibility need not further be discussed, since, in any case, it does not affect the conclusion that differential erosion and geological structure alone have been the determining factors in the development of the basin and its surrounding mountain ridges, which include Mount Difficult (2,657 feet), and which rise to heights of 2,000 feet or more from the plains on the north and north-east. The outer (escarpment) side of the ridge surrounding the basin, which might in its straighter parts have been regarded as a fault scarp, can clearly not be such a feature, because of its sharp curvature round the synclinal axis at the northern end of the basin.

It seems, therefore, that in the case of the Mount Difficult Range and the Wartook Basin, at least, differential erosion, and not Tertiary block-faulting, has been the factor principally concerned in the determination of the topography, and if this be admitted, it follows that a similar amount of differential erosion must have gone on in adjacent parts of the Grampians, since it would be impossible to produce such an amount of erosion in the Wartook district without neighbouring parts having been affected to almost the same extent. Independent evidence of the importance of differential erosion in the southern section of the Grampians is, however, available.

#### THE VICTORIA VALLEY.

In the country known as the Victoria Valley, between the Victoria Range on the west, and the Serra Range on the east, granitic rocks, very probably post-Lower Carboniferous in age, outcrop, and produce on erosion characteristic rounded hills, very different in aspect from the serrate ridges resulting from erosion of the sandstones. These granitic hills attain an elevation of just under 2,000 feet, which is less than 500 feet below the highest parts of the Victoria Range, and there is no suggestion, either on physiographic or geological grounds, that they owe any part of their elevation above the immediately adjoining Glenelg Valley, to block elevation. Here again, the evidence points clearly to an amount of differential erosion sufficient to account for the existence of the observed topographic features in the granitic terrain, in which the maximum relief is little less than that of the adjacent Victoria and Serra sandstone ridges, which must, because of their contiguity to the granite, have undergone a comparable amount of erosion.

## The Structure of the Hall's Gap District.

### WONDERLAND RANGE.

As we have seen, Hart's view of the structure of this district is that the parallel ridges of the Mount Difficult Range, the Wonderland Range, and the Terraces (see Fig. 3) are composed

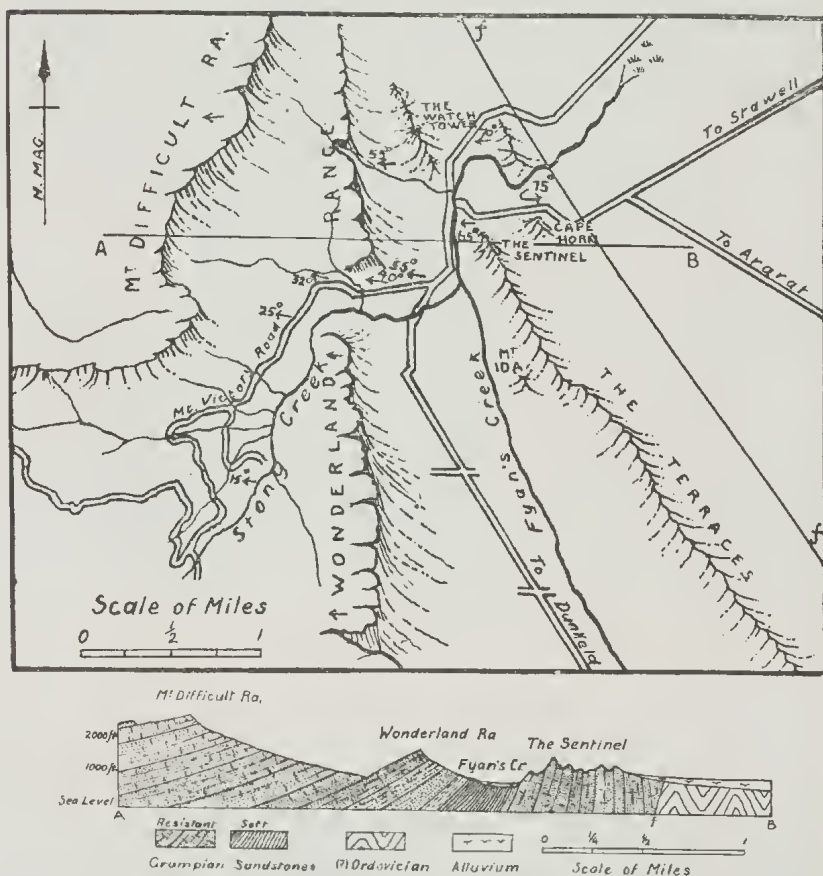


FIG. 3.—Sketch map and geological cross section in the Hall's Gap district. *f.*, probable eastern boundary fault of the Grampians. The dips shown on the map refer to the Grampian sandstones, and the major topographic features are represented as in a bird's eye view.

of the same sandstone formation, repeated by strike faulting, the valleys between them being regarded as fault angle valleys. Although Hart stated that he observed a nearly vertical strike fault in Stony Creek, near Hall's Gap, I could find no evidence of the presence of any but very minor dislocations in the sandstones in that district. Indeed, in the Stony Creek valley at Venus' Bath, there is the clearest evidence, in an excellent



exposure, that the sandstones of the Wonderland Range dip in natural position underneath those of the escarpment face of the Mount Difficult Range (see Fig. 3), which, it has been shown above, is an erosional feature. The stratigraphical evidence, therefore, shows that the valley of Stony Creek is not tectonic in origin, and the genesis of the Wonderland Range cannot be ascribed to faulting, either Tertiary or older. Indeed, as it is traced northwards, the Wonderland Range decreases in importance as a topographic feature, and finally becomes merely a shoulder on the eastern slopes of the Mount Difficult Range. This is probably caused by thinning of the Wonderland sandstones in the north.

There remain to be considered the Fyan's Creek valley and the easternmost ridge of the Grampians in the Hall's Gap district—the Terraces.

#### THE TERRACES.

The structure of this range, which extends for about nine miles in a north-north-westerly direction from the northern end of the Mount William Range, is most instructive. It is composed of massive sandstones, dipping either vertically or a few degrees on either side of the vertical, and may be described as a hogback, or even in places a razorback ridge. In a west-east traverse near Hall's Gap, the westerly dip of the beds in the Wonderland Range is found to increase as one traverses eastwards, from 25 deg. to 55 deg., and the most westerly outcrop of the Terraces sandstones shows a dip of 65 deg. in a westerly direction, increasing to the vertical, and finally becoming overturned (dip 105 deg.) on the eastern edge of this range. The most probable explanation of this increase in dip is that the high dips in the Terraces are due to drag along a major fault line, along which the Grampians sandstones were downthrown. The fault must, of course, be very ancient, antedating the Cretaceous peneplain, at least, since the downthrown beds now constitute a mountainous region, and there can therefore be no doubt that the Terraces have not resulted from Tertiary block faulting, but that they are due to the erosion of beds tilted to high angles before Tertiary times. The razorback ridges of the Terraces illustrate clearly the importance of the dissection of geological structures by erosive agents in determining the topography of the Grampians.

It is interesting to note the similarity between the structure of the Terraces and that of the western edge of the belt of Upper Palaeozoic sediments in Eastern Victoria, extending from Mansfield nearly to Bairnsdale. Similar high dips occur along the western edge of this belt of rocks, very probably due to drag along a more or less meridional boundary fault. It would seem that, perhaps in late Palaeozoic times, extensive block faulting occurred in what is now the Central Victorian Highlands, faulting which to-day influences the topography of certain parts

of the Highlands to a remarkable degree, especially where hard and soft rocks have been brought into juxtaposition by the fault movements.

#### FYAN'S CREEK VALLEY.

It will now be realized that, bounded as it is on the east and west by strike ridges of resistant rock, the presumption is that Fyan's Creek Valley is itself due to erosion, and not to tectonic movement, but it will be as well to consider the geological facts bearing on the origin of the valley. Data relating to the possible presence of a fault along the valley cannot be obtained in most parts, owing to the extensive deposits of alluvium that cover the valley floor, but to the north of Hall's Gap, the valley narrows considerably, and rises to a saddle west of the Watch Tower. The frequent exposures of sandstone which occur along the small creek leading up to the saddle show no evidence of faulting, and none is to be seen in the saddle itself, where, I think, it might reasonably be expected if a fault were present, owing to the massive nature of the beds that would have been involved.

Fyan's Creek Valley is, however, so much larger than the valley of Stony Creek, that if it is not due to faulting, one would expect to find some other factor which might explain its size. This factor, I believe, is the presence beneath the massive sandstones of the Wonderland Range, of beds which are very much softer and less resistant than those sandstones, viz., closely jointed chocolate and banded micaceous sandstones, which have been exposed in a road cutting about 200 yards along the Mount Victory Road from the junction at Hall's Gap. Some idea of the probable relative resistance to erosion of these soft beds and the massive sandstones may be gained from the fact that the latter, in two tests, showed a crushing strength greater than many granites, viz., 11,200 lbs./sq. ins. and 17,500 lbs./sq. ins., while the former may readily be scratched with the fingernail, and break with ease under the hammer into small fragments.

The full extent of these soft sandstones cannot be demonstrated, owing to the covering of scree and alluvium in the Fyan's Creek valley, but it is significant that, where the soft beds are apparently absent or very thin, as in the northern extension of the valley west of the Watch Tower, the valley is narrow, and where the soft beds have been discovered further to the south, the valley becomes much wider. This suggests that the increasing width of the valley in the south may be correlated with an increased development of the soft beds. In earlier descriptions of the geology of the Grampians, the presence of such beds has not been referred to, owing, I think, to the fact that they are readily eroded and become covered with superficial deposits. I have, however, observed sandy shales at the saddle traversed by the road at the southern end of the Victoria Valley, and soft sandstones above the Silverband Falls along the road to Mount Victory, south of Hall's Gap.

### **Summary and Conclusion.**

The arguments presented above have been directed to the demonstration of the following points:—Firstly, that differential erosion is the only process which is adequate to produce certain of the major topographic features of the Grampians; secondly, that in the Hall's Gap district, geological evidences of faulting between the three parallel ridges constituting the Mount Difficult Range, Wonderland Range, and the Terraces are absent; thirdly, that these ranges are separated by valleys which have been excavated by stream erosion, aided, in the case of the Fyan's Creek valley, by the presence of soft beds beneath the sandstones of the Wonderland Range; and fourthly, that the eastern boundary of the Grampians in the Hall's Gap district is probably marked by an ancient fault line, along which the Grampians sandstones were depressed, drag along this fault plane having caused the high dips in the sandstones of the Terraces. I conclude, therefore, that, as Gregory considered, the Grampians are highlands of the Pennine type, and now stand above the surrounding country because they are composed dominantly of relatively very resistant rocks. The sandstone ridges in the Grampians are strike ridges, and the valleys have been excavated by stream erosion, and are not tectonic in origin.

I do not propose to enter at this time into a discussion of the development of the river system in the Grampians, or of the nature of the uplift, which, as part of the Western Highlands of Victoria, the Grampians must have undergone since the last extensive peneplanation, which I believe took place in Victoria in Upper Cretaceous times (Hills, 1933). The nature of the surface at the time of peneplanation, and the type of movement which took place, as well as the geological structure, have all to be considered in any discussion of the development of the stream system, and adequate data concerning these have not yet been accumulated. However, the drainage pattern in the Grampians, and the relations between the streams and the geological structures are, so far as my knowledge goes, in accord with the origin of the Grampians topography outlined above, and are not comparable with the drainage of block-faulted regions in other parts of the world. The Silverband Falls, which Hart considered indicate late movement along a fault line, are, in my opinion, determined by the presence of a resistant sandstone formation crossing the valley of Dairy Creek.

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[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. I., 1936.]

ART. II.—*On the Occurrence of Quartz-Tourmaline Nodules in the Granite of Clear Creek, near Everton.*

By A. B. EDWARDS, Ph.D.

[Read 14th May, 1936; issued separately, 23rd November, 1936.]

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LOCALITY.

THE GRANITE.

THE QUARTZ-TOURMALINE NODULES.

ORIGIN OF THE NODULES.

QUANTITY OF BORON.

REFERENCES.

### Introduction.

The curious development of quartz-tourmaline nodules in the granite of Clear Creek, near Everton, was first recognized by Mr. W. Baragwanath, Director of the Geological Survey of Victoria, in 1932. Phenomena of this type are rare, although they have been recorded from several localities in widely separated parts of the world. Quartz-tourmaline nodules have long been known to occur in the granites of the Tasmanian tin fields of Stanley River (1), and Heemskirk (2), (3), where they are especially well developed. Similar nodules have also been described from an aplitic phase of the Cape Willoughby granite at Kangaroo Island, South Australia (4), from the Dartmoor granite of Devon (5), from aplites in Montana (6), (7), and recently, from the porphyry intrusive stock of the Lllallagua-Uncia tin field of Bolivia (8).

At my request, Mr. J. C. Grieve, Inspector of Mines at Wangaratta, revisited the area, and made a collection of the nodules and the granite. The specimens, together with brief notes on the nature of the occurrence were forwarded to me at Imperial College, but their examination was delayed. The field description of the occurrence, in the following notes, is based entirely upon Mr. Grieve's information.

### Locality.

Clear Creek is a small watercourse draining a granitic catchment of about 25 square miles in the Parish of Byawatha, County of Bogong. As shown in the accompanying sketch map (Fig. 1), it is a tributary of Reedy Creek, which flows into the Ovens River, near Wangaratta.

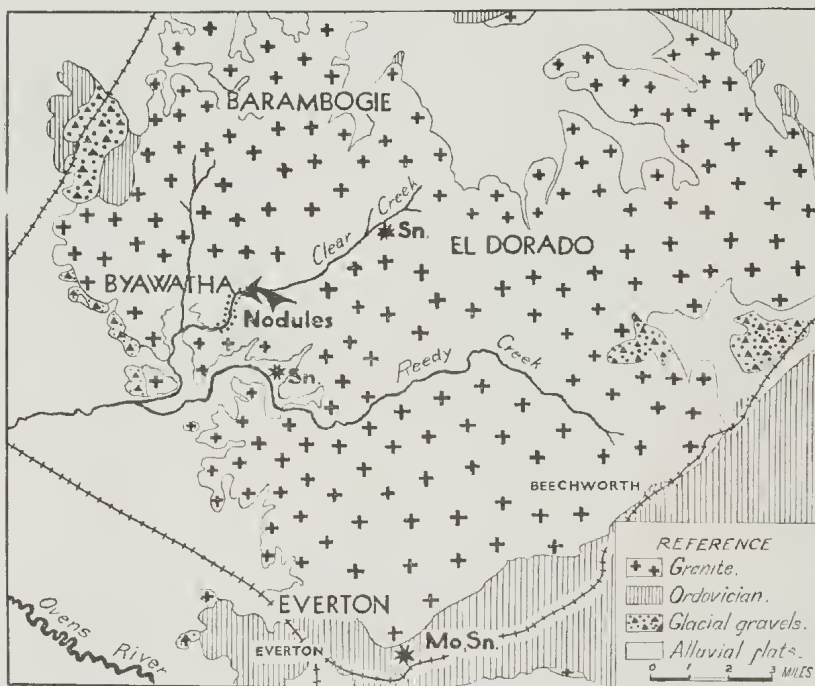


FIG. 1.

Over the lower two miles of its course, Clear Creek flows through a narrow gorge, and it is in this gorge that the quartz-tourmaline nodules are exposed. The stream drops about 250 feet in this section of its course, chiefly in three separate and abrupt falls. Downstream, towards the Ovens Valley, the bedrock is covered to a depth of 30 feet or more by alluvium, and the junction of the granite with the Ordovician sediments cannot be observed. Upstream, for about eight miles, the stream has a slight gradient over a granitic plateau.

### The Granite.

The granite in which the quartz-tourmaline nodules occur is of variable texture, grading rapidly from a fine-grained granite into aplite. It is composed essentially of quartz and orthoclase,

and a lesser amount of oligoclase. Biotite is the only ferromagnesian mineral, and is not abundant. The quartz forms patches about 1 cm. across, which are generally composed of several interlocking, allotriomorphic grains. The orthoclase is frequently sericitized, and forms large crystals up to 1 cm. in length, or it may occur as smaller interlocked grains. It tends to predominate over the quartz. The biotite plates are somewhat chloritized; and the accessory minerals are zircon and apatite.

The proportion of the minerals is much the same in the aplitic phases, but the grain size is considerably finer.

The granite closely associated with the nodules appears to be generally finer-grained than the granite which constitutes the plateau. This association of quartz-tourmaline nodules with a fine-grained phase of the granite in which it occurs is a point in common with most of the known occurrences of such nodules.

### The Quartz-Tourmaline Nodules.

#### DISTRIBUTION.

The quartz-tourmaline nodules persist throughout the two miles of gorge tract of Clear Creek, being especially well exposed in the creek bed. The nodules are not evident in the granite at the sides of the gorge, but Mr. Grieve found them in several boulders which were not *in situ*. Above the gorge section, and in the coarser granite of the plateau, the nodules do not appear to be developed. Much of the granite in these parts is hidden by shallow gravels, but, despite this, Mr. Grieve concluded that the development of the nodules was more marked where the creek channel had cut deepest into the granite.

The distribution along the gorge is variable. In places the nodules diminish in number, and at others they become much smaller than usual—about half an inch in diameter. They constitute about 1 per cent. of the granite in this section, although there are limited areas in which they are more plentiful. At the lowermost of the three falls there is an aplitic dyke, striking north-south with a dip to the east, and small quartz-tourmaline nodules, about half an inch across are developed in the dyke.

The nodules are scattered through the granite, and do not appear to have formed along any defined lines or zones; nor do the longer axes of adjacent nodules show any parallel orientation.

#### DESCRIPTION.

The nodules are ellipsoidal in shape, and average about 2 to 3½ inches in their longest diameter. They vary in size from place to place, but, in any one small area, are all more or less uniform. They may decrease to half size in a distance of about 100 yards,

and then show an increase in another 100 yards. The largest nodule observed was  $5\frac{1}{2}$  inches across, and the smallest about  $\frac{1}{2}$  an inch across.

Where the weathering has been solely atmospheric, as on the boulders on the side of the gorge, the nodules, on account of their greater resistance, form ellipsoidal protuberances, "like warts", on the granite. In the creek bed, however, where they have suffered attrition, they do not protrude, but form elliptical dark patches.

The nodules consist of tourmaline, quartz, a minor amount of orthoclase, often sericitized or kaolinized, and a little muscovite. The tourmaline frequently forms clusters of acicular needles which radiate outwards from the central part of the nodule. It is interstitial to the quartz crystals, and, especially towards the periphery, can be observed replacing the original orthoclase *in situ*. The tourmaline is mostly blue in colour, sometimes greenish-blue, but it grades into small areas of brown tourmaline. The brown tourmaline is probably derived from the original biotite of the granite (9), while the blue tourmaline obviously results from the alteration of the orthoclase. The tourmalinization commences along the cleavages of the felspar (Fig. 2, A), and spreads outwards, so that, in the closing stages of the alteration, the felspar is represented only by parallel inclusions of felspar within the tourmaline (Fig. 2, B). The change is most complete in the central part of the nodules, and towards the peripheries there is an increasing amount of unaltered felspar. The edges of the nodules are irregular, but are sharply defined, indicating the exhaustion of a limited supply of boron and other mineralizers.

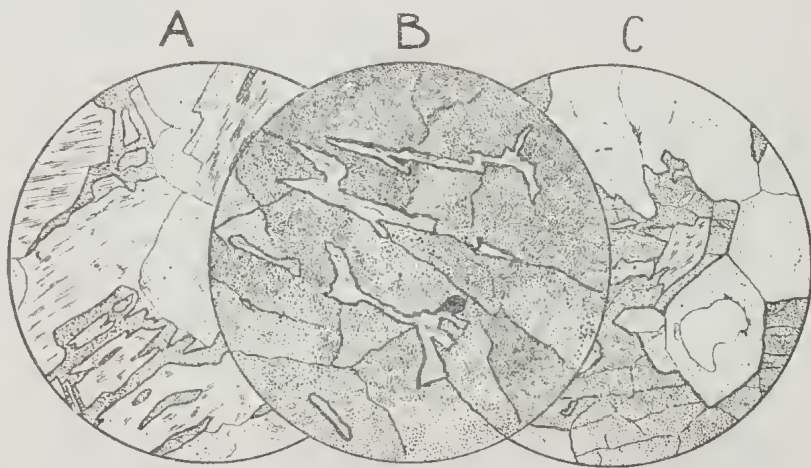


FIG. 2.

The larger areas of quartz consist of interlocking allotriomorphic grains, similar to those in the adjacent, unaltered granite; but the quartz enclosed in, or in contact with, the tourmaline, is often idiomorphic. In some instances these idiomorphic quartz crystals are observed to have an allotriomorphic core, on which later deposition of quartz has built an idiomorphic rim of similar optical orientation (Fig. 2, C). There is also a certain amount of granular, interstitial quartz. This and the secondary rims are probably the residual product of the reaction:—

Orthoclase + boron  $\rightarrow$  tourmaline + quartz.

Usually the quartz and tourmaline are in about equal proportions, but in one specimen the tourmaline almost excludes the quartz, and forms striated prismatic crystals, nearly 2 cms. long, with minute vughs between them.

Zircon is the only other mineral which has been observed in thin section. Any apatite in the original granite has disappeared during the formation of the tourmaline.

Cassiterite is frequently present in the Tasmanian nodules, but has not been observed in those from Clear Creek. In this they resemble the Cape Willoughby, Dartmoor, and Llallagua-Uncia nodules.

Cassiterite occurs, however, in the granite, although no tin lodes are known to exist. A considerable amount of stream tin has been mined along the upper section of Clear Creek (Fig. 1), where it is associated with a tourmaline sand, and an occasional colour of gold. Mr. Grieve considers it probable that the stream tin is derived from the breaking up of numerous minute veinlets of stanniferous quartz traversing the granite. Cassiterite and molybdenite are found in the Ordovician sediments at the southern contact of the granite, and have been mined.

### Origin of the Nodules.

In common with the similar nodules from elsewhere, these quartz-tourmaline nodules occur in a more fine grained granite than that making up the mass of the stock in which they occur; the tourmaline is mostly the blue aluminous variety, and has replaced orthoclase feldspar *in situ*; and the development of the nodules appears to post-date the intrusion of aplite material into the granite.

The earlier writers (1, 2, 3, 6, 7), considered such nodules to represent magmatic segregations, although Barrell (6) did not entirely exclude the possibility of a pneumatolytic origin for them. The later writers (4, 5, 8), consider them to be of pneumatolytic origin, on account of the *in situ* replacement of the feldspars. The most complete picture of their origin is given by Tilley (4). He pictures a reduction of pressure accompanying the intrusion of aplite into the semi-crystalline granitic magma.



This reduction of pressure caused the development of bubbles of mineralizers, which rose in the viscous magma until they reached the crystal mesh of quartz and feldspar, when they attached themselves to these crystals. With further cooling the mineralizers became active, and the boron attacked the feldspars and biotite, converting them into aluminous tourmaline, at the same time depositing the excess silica as secondary quartz. Brammall (5) also suggests that such nodules have developed by an "auto-pneumatolysis" of this type, or that such bubbles have attacked small basic segregations or xenoliths of biotite and plagioclase. Tilley's explanation of the Clear Creek nodules seems the more probable, since there is no evidence of the former existence of such xenoliths.

### Quantity of Boron.

The average  $B_2O_3$  content of tourmaline is approximately 10 per cent. Therefore, since the proportion of quartz and tourmaline in the nodules is about equal, and the nodules constitute about 1 per cent. of the granite in which they occur, the  $B_2O_3$  constitutes about 0.05 per cent. of the granite, i.e., 5 tons of  $B_2O_3$  or 1.5 tons of Boron per 100,000 tons of granite. No figures appear to be available which would permit of a comparison with the average  $B_2O_3$  content of granites.

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ART. III.—*The Mineralogy of the Sand Fractions of Some Victorian Soils.*

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[Read 14th May, 1936; issued separately, 23rd November, 1936.]

INTRODUCTION.

IMPORTANT ASPECTS OF SOIL MINERALOGY:—

- The Origin of the Soil.
- The State of Maturity of the Soil.
- The Fertility of the Soil.

METHODS OF INVESTIGATION:—

- Coarse Sand.
- Fine Sand—
  - Note on specific gravity separations.
  - Quantitative methods used in this work.

STATISTICAL ANALYSIS OF RESULTS.

MINERALOGY OF THE SAND FRACTIONS STUDIED AND DISCUSSION OF RESULTS.

- Soils on Jurassic Sandstones.
- Soils on Quaternary Deposits.
- Soils on Basalt.

CONCLUSIONS.

ACKNOWLEDGMENTS.

REFERENCES.

**Introduction.**

The study of the minerals present in soils has received comparatively little attention, although the results of such a study are important in connection with the origin, development, and fertility of the soil. To study the application of soil mineralogy to these problems, twelve Victorian soils were selected from areas with different geological characteristics. Five samples, including two profiles, were taken from Jurassic areas, two from Quaternary deposits, one from the Older Basalt, and four from the Newer Basaltic areas, including one profile of four horizons. This paper deals with the mineralogy of these soils, and with the methods found most useful for this type of work. Before the discussion of these methods, a brief outline of the general principles of soil formation is given.

Soil is the result of the action upon the parent material of various forces which cause the disintegration of the parent rock into individual mineral grains, and the further disintegration and decomposition of these grains. The rate of decomposition depends, among other things, upon the amount of surface exposed to weathering, and decomposition therefore becomes more rapid as the material becomes finer, until at a certain size, the particles are decomposed as fast as they reach that size by disintegration. For this reason, the primary minerals (orthoclase, plagioclase, augite, etc.) occur mainly in the coarser fraction of the soil and are rare in the fraction having a diameter of less than 0.002 mm. (Marshall, 1935 i.). Together with the breaking up of the original minerals, formation of secondary minerals takes place. These minerals, especially the clay minerals (beidellite  $\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot n\text{H}_2\text{O}$ ; nontronite,  $\text{Fe}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot n\text{H}_2\text{O}$ , etc.) are found mainly in the finer fractions of the soil, particularly in the fraction with less than 0.001 mm. diameter. There is, of course, an overlap in the size distribution of these two classes of minerals.

The relation to the parent material is shown by the primary minerals, while the nature of the secondary minerals depends more upon climate than upon parent rock. These secondary minerals make up, wholly or in part, the colloidal fraction of the soil, and this gives important characteristics to the soil profile. In some cases, the effect of climate is so great that soils developed from different parent materials, but under the same climatic conditions, show a general similarity; they are then classed as belonging to the same soil group (Podzol, Chernozem, etc.). In other cases, however, climate has not been able to obliterate the effect of marked textural or chemical differences in the parent rock. Both cases are shown excellently in the soil map of the U.S.S.R., where belts of podzol, degraded chernozem, chernozem, chestnut and desert soils follow each other from north-west to south-east as the climate gets steadily drier and hotter. At the same time, podzol tongues formed on river sand dunes project into the chernozem belt, and the chernozem occurs on calcareous marl within the podzol belt.

This paper deals mainly with the primary minerals of the soil. The investigation of the finer material requires special apparatus and technique, because most of the usual microscopic methods for the identification of minerals fail for particles smaller than 0.02 mm. diameter. Highly accurate determinations of refractive index are necessary, together with the use of the ultramicroscope and X-ray analysis if possible (Marshall, 1935 ii.). Apart from the difficulty of the methods, the information supplied by the secondary minerals relates to other problems than those considered here.



### Important Aspects of Soil Mineralogy.

Soil mineralogy is important in connection with the following three subjects:

1. *The Origin of the Soil.*—The primary minerals give some indication of the parent material, and by comparison with the underlying rock, one can determine whether the soil has been formed in situ or whether foreign material has been added. Characteristic minerals may indicate the source of such foreign material (cf. Elder and McCall, 1936).

2. *The State of Maturity of the Soil.*—The degree of disintegration and decomposition of the minerals gives a measure of the maturity of the soil. A mature soil, i.e., one which has developed the profile appropriate to the climate, contains only the most resistant mineral species (see No. 11). Since resistant minerals can be of little use for plant foods, a mature soil under a high rainfall may well be agriculturally poor, even though its parent material was rich in the necessary elements for plant growth. A soil which contains unweathered grains of readily decomposable primary minerals must be immature. This immaturity may be due to geological youth, as in the case of the basaltic tuff of Mount Gambier, the soil on which contains olivine crystals 1 mm. in diameter, and abundant clusters of small fresh augite crystals. Immaturity may also be due to the fact that erosion of weathered surface soil has kept pace with decomposition (see No. 17).

3. *The Fertility of the Soil.*—The soil minerals are important also as a source of plant foods. This question has been dealt with by Vageler (1933), who states that—"the permanence of fertility in a soil varies with its content of minerals still liable to decomposition". While this may be especially true under the more rapid weathering of tropical climates, it must apply also to temperate climates. Some writers believe that richness or poverty in potassium often depends on the presence or absence of potassium minerals, which, it is thought, some plants can use directly as a source of potassium (Van Baren, 1935).

The value of a given quantity of a mineral depends on the amount of surface exposed to weathering or to plant roots. In the coarse sand, this is insignificant, and the coarse sand minerals are therefore important only as a source of supply of the finer fractions. The amount of surface is much greater in the fine sand and still greater in the silt, and the percentage of mineral in these fractions is therefore an indication of fertility. While the silt fractions have not been studied in this work, the presence of a mineral in the fraction of 0.02 to 0.04 mm. diameter shows that it exists also in the silt. The results given for the percentage of mineral in the fine sand are therefore valuable for indicating fertility.

## Methods of Investigation.

### COARSE SAND.

Qualitative mineral analysis may be used to give some indication of the parent material of a soil, but for the questions of degree of maturity and soil fertility, quantitative results are much more useful. The fraction of the soil coarser than 2 mm. diameter, the gravel, usually forms a very small part of the soil and consists of concretions of lime or of iron oxide, or decomposing rock fragments. For this reason, the quantitative analysis of these Victorian soils was done only on the sand fractions. The coarse sand, 2 mm. to 0.2 mm., usually consists of individual minerals. In the soils examined, the coarse sand contains only a few mineral species, as would be expected, since only those minerals which are resistant to both disintegration and decomposition could persist in such large grains in a mature soil. With a few exceptions, the coarse sand of the Victorian soils studied consists almost entirely of quartz. The coarse sands were examined under binocular and petrographic microscopes, and in a few cases where several minerals were present, an approximate quantitative estimate of composition was made by counting the number of grains of each mineral present in a sample of 200, using a divided stage.

### FINE SAND.

The minerals in the fine sand (0.2–0.02 mm.) were identified by using the petrological microscope and the usual optical methods for grains, especially as set out by Fry (1933). Refractive index was determined by immersions in standard solutions, and double refraction was measured by a Berek Compensator, the thickness of the grain being estimated by focusing on a top and bottom facet and reading the distance between the two focal positions on the fine adjustment screw. Such determinations give approximate results only, but are often very useful. Optical character was determined when necessary, and in a few doubtful cases, the minerals were rubbed down to flat plates to permit identification. In all cases, comparison was made with standard mounts of known detrital minerals or crushed mineral fragments. The rarer heavy minerals were in some cases concentrated, for easier identification, by specific gravity separation in bromoform.

#### *Note on Specific Gravity Separations.*

Unfortunately, such separations into fractions having different specific gravity could not be used as a basis for quantitative work for the particular problems considered here. In the first place, it is difficult to get accurate results with specific gravity separations of fine material, since the effects of surface tension interfere seriously with the settling of the minerals. Hendrick and Newlands (1923 and 1925) and Hart (1929) aimed at dividing the minerals into three groups according to their specific

gravity, and worked on the fine sand as defined by the British Classification, 0.2 to 0.04 mm., and Hendrick and Newlands state that the finer material does not give accurate results when treated in this way. The fraction from 0.04 to 0.02 mm. contains many important soil minerals, and in some of the soils described in this paper, valuable information would have been lost if it had been neglected. In more recent work, Elder and McCall (1936) have adopted the International Classification, and have made specific gravity separations of the fraction from 0.2 to 0.02 mm., but the writer has been unable to obtain satisfactory separations of the finer material by this method.

In the second place, division into the three groups used by these authors is insufficient for the purpose of this work. It is important to make distinctions between the rock fragments and light feldspars which make up the first group, the quartz and heavier plagioclases of the second group, and the ferromagnesian silicates and accessory minerals of the third, since these minerals have very different values in the soil.

Specific gravity separations using tetrabromoethane and nitrobenzene have been carried out recently by Volk (1933), with an elaborate process aimed at removing the films of water and air on the grains, since these films interfere with the separation of the minerals. He separated the soil minerals into six groups, and claimed to have obtained extremely accurate results with material down to 0.0003 mm. diameter, but his groups fail to differentiate quartz from plagioclase. Since the specific gravity of quartz is 2.65–2.66, and the plagioclases range from 2.62–2.76, it is obviously impossible to use specific gravity as a basis for separation of quartz and some of the intermediate plagioclases, however accurate the process. Such a separation was necessary in the work carried out here, so specific gravity separations using heavy liquids were abandoned. Where the heavy minerals of the parent material include fairly stable primary minerals, a study of the heavy fraction of the soil may be sufficient for purposes of correlation (Carroll, 1931 and 1933). In this case the actual proportion of heavy to light fraction is not important, and accuracy of separation is not essential. Where the heavy minerals of the parent rock are unstable, the heavy fraction of the mature soil formed from it is likely to consist of foreign material (see Nos. 10 and 11), and no correlation with parent material or indication of degree of maturity will be shown by this fraction. In either case, since the heavy minerals form very small proportions of the fine sands, fertility cannot be estimated if the light fraction is neglected.

#### *Quantitative Methods Used in This Work.*

The quantitative method used in this work consisted of counting the number of grains of each mineral present in a definite sample, and measuring the average diameter of the

grains. Statistical theory indicates that to give satisfactory results 500 grains of each sand fraction must be counted (see below), and the counting of such large numbers of grains by the usual method, using a subdivided stage or eyepiece (Fry, 1933, p. 31), is a tedious process. It is considerably quicker and easier to use a mechanical stage and traverse the slide, recording the nature of the grain passing under the crosswires by means of a chosen letter on a typewriter. The eyestrain involved is greatly reduced by this method, since only the mineral in the centre of the field is examined, and it is not necessary to look up from the microscope to record the identity of the grain. Time is also saved, since the letters may be typed with the left hand while the stage is moved with the right. If the minerals are readily identified, 500 grains may be recorded in about 45 minutes.

A line traverse made at random on a mixture of equal numbers of large and small grains will obviously cross more of the larger kind, causing an error in the result of the count. This was tested with a slide prepared from a mixture of large quartz grains and small zircon crystals. Counts were made using a subdivided eyepiece, as well as by the method of traversing outlined above, and the correct result was found by photographing the slide and counting all the grains on an enlargement. The results given by using the subdivided eyepiece showed good agreements with the actual numbers of mineral grains present, but with the traversing method, although the results agreed well with one another, the quartz grains were more likely to be recorded than the zircons. Measurements of the average diameter of the grains showed that the number of grains counted on a line traverse was proportional to the number present multiplied by the average diameter. Miss M. Barnard, then on the staff of the Melbourne University, was good enough to investigate this problem mathematically, and she found that the above result was obtained theoretically, if the mineral grains were assumed to be spherical.

The volume of each mineral in the fine sand is proportional to the number of grains present multiplied by the mean value of the cube of the diameters. It is therefore proportional to the number of grains counted on a line traverse divided by the mean diameter, and multiplied by the mean cube of the diameter.

These two required means were obtained by making a number of measurements with a micrometer eyepiece. To avoid the selective effect caused, as described above, by line traversing, all the grains coming within a band wide in comparison with their diameter were measured. The diameter of each individual grain was taken to be the mean of its longest and shortest diameters. No attempt was made to measure the thickness of the grains, although the focusing method (Fry, 1933, p. 74) was available, because the value given would be at best approximate,

and the measurements would take a long time. Most soil minerals tend to approach the spherical during weathering, and the longest and shortest diameters were usually found to be close to one another. The fact that results using the mean of these two measurements agreed with Miss Barnard's theoretical results assuming the grains to be spherical, showed that no important error would be caused by neglecting to measure the thickness of the grains.

Measuring the diameter of the grains is a tedious process, and, if approximate estimations of volume are sufficient, may be omitted. In this case, the method of counting by line traversing gives a better indication of volume proportions than methods using a subdivided eyepiece, for if  $n$  represents the number of grains of the mineral present, and  $d$  the diameter of a grain, accurate volume proportions are given by  $n$ , (mean  $d^3$ ), counting on a line traverse gives  $n$  (mean  $d$ ), while counting with a subdivided eyepiece gives  $n$ . Line traversing therefore makes some automatic correction for grain size without the necessity of measuring the diameter of the grains. The results of this work show that counts made on a line traverse give fair approximation to volume proportions if the minerals concerned are not of very different sizes. If the grain sizes differ greatly, and it is important to estimate small differences in volume, measurements of diameter and calculation of volume as  $n$ , mean  $d^3$  are necessary.

Two figures for the amount of each mineral are quoted in Table I., (*a*) the percentage in the fine sand fraction, and (*b*) the percentage in the soil. As regards fertility, the percentage of the mineral as fine sand in the soil is the more valuable result. The leaching down of clay into the subsoil, which is common among the podzolised soils of Southern Victoria, does not affect the percentage of mineral in the fine sand (*a*), but it increases the percentage of mineral in the soil (*b*) in the upper horizons at the expense of the lower. For this reason, it is better to choose samples that have been taken from similar depths, when comparing soils from different localities. In the present work, the sub-surface has been taken, since the surface soil is usually contaminated by the addition of wind-blown material (see below).

### **Statistical Analysis of Results.**

This method of calculating the percentage volume of any mineral in the fine sand of the soil, although free from errors of identification, involves the following uncertainties:—

1. In the counting of the grains. The standard error of a method such as the one used is given by the formula—

$$\text{s.e.} = \sqrt{p.q.n.}$$

where  $p$  = the fraction of the whole represented by the particular mineral.



$$q = (1 - p)$$

$n$  = the number of grains counted.

e.g., for plagioclase in No. 10, 20 grains occurred in a count of 500.

$$\text{s.e.} = \sqrt{\frac{20}{500} \times \frac{480}{500} \times 500} = 4.4 = 22\%.$$

As in all work of this kind, the counting of 500 grains is a compromise. A smaller number would give unduly large errors for the important minerals, and any further reduction of error by counting a larger number of grains would involve extra work that would not be warranted by the improvement of results. The variation between counts on duplicate slides was found to be the same as the variation between counts made on the one slide, i.e., the sampling error in making the slide is not serious. These variations are what would be expected in dealing with samples of 500.

2. In the calculation of the mean value of the diameter  $d$ , the mean value of  $d^3$ , and the ratio of the latter to the former, the standard error of each of these means is taken to be—

$$\sqrt{\frac{\sum x^2}{n(n-1)}}$$

where  $x$  = the deviation of the individual value of  $d$  or of  $d^3$  from the respective mean,

$n$  = the number of grains measured.

This formula assumes a normal distribution for both  $d$  and  $d^3$ . The distribution of both these variables is in fact skew with a maximum occurrence near the lower limit of the fine sand, but no serious error will be caused by using the formula. The number of minerals measured in any one sample depended on the spread of the grain size and the importance of the mineral. To obtain reasonably small percentage errors, it was found necessary to measure 100 grains of such a mineral as quartz, which has a very wide spread of grain size, while for the small plagioclases such as occur in Nos. 8 and 9, 25 measurements only were made. The accuracy aimed at in this work must, of course, depend on the time available. Measurement of 100 grains usually takes about 60 minutes.

A further error is involved in dividing the mean of  $d^3$  by the mean of  $d$ . The calculation of this error presents a complex problem, which may be avoided by assuming that the percentage error of the quotient equals the percentage error of  $d^3$ . This seems likely to give a maximum figure for the required error.

E.g., for augite in Table I., No. 17, working in units of .01 mm.,

Mean  $d = 5.38$ , standard error 0.29 (5.4%).

Mean  $d^3 = 266$ , s.e. 46.2 (17.4%).

Ratio of  $d^3$  to  $d$ , 49.4, s.e. 8.7 (17.4%).

3. In the calculation of the volume as number of grains counted multiplied by the ratio just discussed. The error of a product is given by the formula—

$$\text{var. } AB = \bar{A}^2 \text{ var. } B + \bar{B}^2 \text{ var. } A + 2 \bar{A}\bar{B} \text{ covar. } AB.$$

where  $\bar{A}$  and  $\bar{B}$  are the means of  $A$  and  $B$ , and var. and covar. stand for variance and covariance. Since the covariance of  $A$  (number of grains counted) and  $B$  (ratio of mean  $d^3$  to mean  $d$ ) seems likely to be relatively small, the simpler relation is used—

$$\text{var. } AB = \bar{A}^2 \text{ var. } B + \bar{B}^2 \text{ var. } A.$$

The standard error (i.e., the square root of the variance) has been found for each of the volumes and expressed as percentage of the volume.

E.g., for augite in sample 17,

$$\bar{A} = 75, \text{ var. } A = 64.$$

$$\bar{B} = 49.4, \text{ var. } B = 75.7.$$

$$AB = 3705, \text{ var. } AB = 75^2 \times 75.7 + 49.4^2 \times 64 = 664,850.$$

$$\text{s.e. of } AB = 815 = 22.0\%.$$

4. To find the percentage volume of each mineral, the different volumes are added together, and the percentage of each is calculated in terms of the whole. This involves uncertainties in the addition of a number of variables, and a further uncertainty in the division of each one by the whole. While the former error can easily be calculated, no suitable formula is known for the error of a quotient in such a case as this. Failing such a formula, the error of the product  $nd^3$  is given for each mineral.

These methods, however, only give the error of one sample. If we wish to determine whether this sample belongs to a particular soil type, or whether it differs from another sample, allowance must be made for the inherent variability of soil. No figures are available to indicate the variability of minerals within the one soil type, but it is likely that the standard deviation of mineral figures due to this cause is 10–20%, as is found with the chemical properties of the soil.

Where only one sample of a soil type is available, the error is estimated as—

$$\sqrt{(\% \text{ s.e.})^2 + (20\%)^2}.$$

Where several samples, which are known on other grounds to belong to the same soil type, are available, the error can be worked out on the assumption that these are random samples of a single population.

## Mineralogy of the Sand Fractions and Discussion of Results.

### 1. SOILS ON JURASSIC SANDSTONES.

#### No. 1. Leongatha, S. Gippsland. 6-12".

##### *Coarse Sand.*

Quartz.—Angular to sub-rounded, somewhat ironstained in cracks and hollows. Inclusions common, apatite, iron oxide, fluid.

Plagioclase.—R.I. close to 1.545 and optically negative, oligoclase. Grains rounded, generally clouded and somewhat altered.

Orthoclase.—Irregular grains, sometimes altered, but generally quite clear and fresh.

Rock.—Irregular fragments.

##### *Fine Sand.*

Quartz.—As in Coarse Sand.

Plagioclase.—As in Coarse Sand.

Orthoclase.—As in Coarse Sand.

Iron oxide.—Small irregular grains. Magnetite or ilmenite, alteration to leucoxene in some cases.

Tourmaline.—Small stumpy prisms with rounded terminations. Brown most common, some blue-grey.

Zircon.—Small grains, usually completely rounded. Some prisms with rounded terminations.

Apatite.—Small stumpy prisms, much corroded.

(?) Nontronite.—Irregular fibrous grains, often encrusting on the other minerals. See No. 11 for optical properties.

Sponge spicules, epidote, brown anatase and rutile also present.

#### No. 2. Near Beech Forest, Otway Ra. 4-8".

Principal minerals similar to those of No. 1. Apatite, anatase, and rutile were not observed, and garnet and sphene are present.

#### No. 3. Merino, Western District. 0-4".

Principal minerals similar to those of No. 1. The grains of orthoclase are larger and usually quite clear and unweathered. Epidote, anatase, and rutile were not observed, and biotite is present.

#### No. 4. Poowong, S. Gippsland. 0-4".

#### No. 5. Ditto. 12-15".

Principal minerals similar to those of No. 1. Anatase and rutile were not observed, and garnet and apatite are present.

#### No. 6. Strzlecki, S. Gippsland. 0-4".

#### No. 7. Ditto. 18-24".

Principal minerals similar to those of No. 1. Anatase and rutile were not observed, and garnet and apatite are present.



The parent material of these Jurassic soils is a felspathic sandstone or mudstone having similar characteristics in the three Victorian outcrops of the Strzelecki, Otway and Casterton areas. It consists of quartz, plagioclase, orthoclase, biotite and chlorite, in a fine ground mass (Richards, 1910 and Skeats, 1935). Rosiwal tests on two samples from Apollo Bay and Barramunga gave the following results:—

Apollo Bay.—Quartz, 11% ; feldspar, 25% ; matrix, 64%.

Barramunga.—Quartz, 12% ; feldspar, 33% ; matrix, 55%.

The orthoclase-plagioclase ratio of the rock could be determined only by chemical analysis. Some of the feldspar grains are fairly fresh, while others show advanced decomposition. The occurrence of unusual minerals such as anatase, garnet and sphene in the soils, suggests that the study of the heavy minerals of the Jurassic rocks might give interesting information as to the origin of this series in Victoria.

The soils studied from these rocks show a remarkably high content of feldspar, which occurs even in the coarse sand. Feldspars are usually regarded as a comparatively unstable mineral group, the presence of undecomposed feldspar in a sediment being taken as evidence of deposition very close to the source (arkose), or of arid or glacial conditions of deposition (Mackie, 1899). Also, as already stated, some writers think that plants can use orthoclase directly as a source of potassium. It would be thought, then, that small grains of feldspar would be too readily soluble to persist in soils such as these, which have been exposed to considerable leaching since the Pliocene period (Hills, 1935). The feldspars of the Jurassic rocks, orthoclase and acid plagioclase, are more stable than the basic plagioclases which occur in the Victorian basalts (Mackie, 1899), but the presence of such large amounts of these feldspars, as compared with the almost complete decomposition of the labradorite in mature basaltic soils (see Nos. 10, 11, 12), seems to show either that the stability of orthoclase and oligoclase is greater than is generally imagined, or that these Jurassic soils are immature.

The two profiles from the South Gippsland area show no differentiation of horizons. There has been no appreciable washing down of clay from the surface, and the mineral composition of the soil is not significantly different in the different levels. This may be partly the result of the considerable artificial disturbance of the soil which takes place during the clearing of the land. This involves the grubbing out of tree stumps, scraping to level the resulting uneven surface, and ploughing before sowing the land down to pasture.

The soil from Beech Forest, however, was taken from uncleared forest country, and no artificial factors can be involved. Profiles have not been collected from this area, but the soil

described and another sample from the same locality show a high percentage of felspar in the 4-8-in. level. The comparative immaturity of these soils appears to be due to erosion on a steep slope, and this factor must be concerned to an even greater extent in the cleared country of Gippsland and on the sloping areas of the Casterton district. The importance of the factor of soil erosion could be determined only by collecting numerous profiles from areas having different slopes and different vegetation. Up to the present time, such a detailed study has not been possible.

The relatively high fertility of these soils on Jurassic sediments appears to be correlated with the presence of the felspars in the soil minerals, orthoclase felspar being particularly important.

## 2. SOILS ON QUATERNARY SANDS.

No. 8. Wannon Falls, Western District. 6-12".

### *Coarse Sand.*

Quartz.—Clear grains, generally somewhat rounded.

Buckshot.—Round polished grains of hydrated iron oxide.

### *Fine Sand.*

Quartz.—Larger grains somewhat rounded, smaller angular. Usually clear, liquid inclusions common.

Plagioclase.—Grains all rounded, cloudy and too greatly altered for further identification.

Iron oxide.—Magnetite or ilmenite. Extremely small and irregular grains.

Tourmaline.—Small irregular grains or rounded prisms, yellow to brown most common, some green.

Zircon.—Small rounded grains or prisms with rounded edges.

(?) Nontronite.—Yellow fibrous fragments, varying size.

Pale brown biotite and sponge spicules also present.

No. 9. Near Orbost, E. Gippsland. 4-14".

Principal minerals similar to those of No. 8. A few much corroded prisms of apatite occur.

Very little is known about the Quaternary deposits which form the parent material of these soils, but they are thought to be largely alluvial or aeolian. The soil minerals are almost entirely of resistant species common to sedimentary deposits, but the presence of plagioclase was unexpected. The grains of plagioclase show great decomposition, and have probably been derived from neighbouring igneous rocks, the Western District basaltic areas in the case of No. 8, and the East Gippsland granodiorites in the case of No. 9. These granodiorites may also be responsible for the trace of apatite in the Orbost soil. Both these soils are infertile, and this may be correlated with the high quantity of sand, almost entirely quartz, which is present.

3. SOILS ON BASALT.

No. 10. Near Woorndoo, Western District. 12-24".

*Coarse Sand.*

Quartz.—Rounded to sub-angular. Inclusions of apatite, zircon, rutile (sagenite webbing), and liquid.

Buckshot.—Round polished grains.

Plagioclase.—Irregular grains, decomposition advanced along cleavages.

*Fine Sand.*

Quartz.—Larger grains rounded, smaller angular.

Plagioclase.—Irregular grains, usually cloudy and decomposed but occasionally clear.

Iron oxide.—Magnetite or ilmenite. Small irregular grains.

Olivine.—Small clear angular fragments.

Tourmaline.—Small rounded grains and stumpy prisms with rounded edges. Brown and blue.

Zircon.—Small rounded grains and prisms with rounded edges.

(?) Nontronite.—Yellow to brown encrusting fragments, size variable.

Sponge spicules are also present.

No. 11. Macarthur, Western District. 18-40".

Principal minerals were the same as those of No. 10, except that plagioclase was not observed in the coarse sand. The secondary mineral which has been recorded as (?) nontronite is common in the fine sand. In colour it ranges from pale yellow to deep red brown. The R.I. is between 1.570 and 1.670, and is close to 1.635 in most of the grains, agreeing with the R.I. for nontronite as given by Marshall (1935, ii). The mineral is fibrous in habit, often encrusting on other grains, so its double refraction was not estimated.

No. 12. Dixie, near, Terang, Western District. 0-8".

No. 13. Ditto. 12-18".

No. 14. Ditto. 27-60".

No. 15. Ditto. 60-76".

Principal minerals similar to those of No. 10. The plagioclase grains appeared to be larger and less decomposed in the lower levels than near the surface. Small fragments of augite were also present, and appeared to be more common in the lower levels.

No. 16. Nilma, near Warragul, Gippsland (on Older Basalt). 10-20".

Principal minerals similar to those of No. 10. Typical buckshot gravel is not present in the coarse sand, but decomposed limonitic material occurs. The grains of plagioclase in the fine sand are all small and extremely decomposed.

No. 17. Birregurra, Western District (immature soil on stony rise). 0-3".

*Coarse Sand.*

Quartz.—As in No. 10.

Rock.—Fragments of decomposing basalt.

Plagioclase.—Clear irregular fragments. Labradorite.

Augite.—Irregular fragments, decomposing along cleavages. Light brown with titanium violet tinge.

TABLE I.—MINERALOGY

No.	Locality.	Underlying Rock.	Depth.	Coarse Sand.						Percentage of Soil.
				Percentage of Soil.	Mineral Composition.					
					Quartz.	Rock.	Plagio- clase.	Ortho- clase.	Buck- shot.	
1	Leongatha ..	Jurassic Sandstone	9-18"	9	57	3	35	5	—	40
2	Near Beech Forest	Jurassic Sandstone	4-8"	2	54	15	29	2	—	15
3	Merino ..	Jurassic Sandstone	0-4"	0.3	Com.	Pres.	Com.	Pres.	—	35
4	Poowong ..	Jurassic Sandstone	0-4"	6	Com.	Pres.	Com.	Pres.	—	44
5	Poowong ..	Jurassic Sandstone	12-15"	11	Com.	Pres.	Com.	Pres.	—	44
6	Strzlecki ..	Jurassic Sandstone	0-4"	3	Com.	Pres.	Com.	Pres.	—	26
7	Strzlecki ..	Jurassic Sandstone	18-24"	4	Com.	Pres.	Com.	Pres.	—	27
8	Wannon Falls, Western District	Quaternary Sand	10-20"	38	Flood	—	—	—	Pres.	32
9	Near Orbost	Quaternary Sand	4-14"	58	Flood	—	—	—	Pres.	28
10	Woorndoo, Western District	Newer Basalt	12-24"	1	Flood	—	Tr.	—	Tr.	9
11	Moyne Falls, near Macarthur	Newer Basalt	18-40"	1	Flood	—	—	—	Tr.	5
12	Dixie, near Terang	Newer Basalt	0-8"	6	Flood	—	—	—	Rare	49
13	Dixie, near Terang	Newer Basalt	12-18"	11	Com.	—	—	—	Com.	38
14	Dixie, near Terang	Newer Basalt	27-60"	4	Flood	—	—	—	Rare	20
15	Dixie, near Terang	Newer Basalt	60-76"	2	Flood	—	—	—	Tr.	15
16	Nilma, Gippsland	Older Basalt	10-20"	2	Flood	—	—	—	—	21
17	Birregurra ..	Newer Basalt, Stony Rise	0-3"	13	60	39	Tr.	—	—	27

NOTE.—The figures for minerals in the fine sand represent—1. Number of grains in count  
 3. Percentage mineral in fine sand. 4. Percentage mineral in soil. In some cases the brackets are percentage standard errors.

## OF SAND FRACTIONS.

## Fine Sand.

## Mineral Composition.

Quartz.	Plagio- clase.	Ortho- clase.	Iron Oxide.	Augite.	Olivine.	Zir- con.	Tour- maline.	Apa- tite.	? Non- tronite.	Rock.	Sponge Spicules.
248 (4) 74 (16) 55 (16) 22	215 (5) 65 (13) 42 (14) 17	11 (30) 43 (14) 1.4 (33) 0.6	3	—	—	4	3	1	—	—	9
224 (5) 78 (16) 50 (17) 7	235 (5) 71 (16) 47 (18) 6	11 (30) 55 (14) 1.7 (17) 0.3	9	—	—	3	3	—	11	—	4
253 (4) 51 18	141 (7) 28 10	59 (12) 12 4	6	—	—	1	1	—	7	—	32
276 (4) 55 24	149 (6) 30 13	36 (16) 7 3	11	—	—	6	—	1	10	—	11
224 (5) 45 20	170 (6) 34 15	52 (13) 10 4	13	—	—	2	—	—	27	—	11
254 (4) 51 13	181 (6) 36 9	54 (13) 11 3	3	—	—	1	2	—	1	—	4
221 (5) 44 12	189 (6) 38 10	59 (12) 12 3	5	—	—	2	2	—	15	—	7
463 (1) 128 (16) 99 32	14 (26) 12 (20) 0.3 (29) 0.1	—	7	—	—	8	3	—	5	—	—
464 (1) 87 (17) 98 28	15 (25) 19 (23) 0.7 (34) 0.2	—	4	—	—	6	1	1	2	—	7
456 (1) 50 (13) 96 9	20 (22) 25 (21) 2.1 (30) 0.2	—	9	—	1	5	3	—	6	—	—
353 (13) 51 (13) 81 (14) 4	35 (16) 14 (13) 2.2 (21) 0.1	—	12	—	—	3	2	—	80 (10) 39 (19) 15 (22) 0.8	—	6
438 (1) 88 43	14 (26) 3 1	—	8	—	—	5	1	—	9	—	25
427 (1)	17 (24)	—	15	—	—	2	1	—	26	—	12
408 (2)	26 (19)	—	14	—	1	3	1	—	45	—	2
416 (2)	34 (16)	—	15	1	1	6	1	—	24	—	2
458 (1) 92 19	7	—	12	—	—	3	6	—	8	—	6
226 (5) 67 (18) 58 (19) 16	92 (9) 49 (18) 17 (20) 3.7	—	70 (11) 25 (28) 7 (30) 1.8	75 (11) 49 (17) 14 (20) 3.8	18 (23) 17 (13) 1.2 (27) 0.3	2	1	—	—	11 (30) 48 (22) 2.0 (37) 0.5	5

of 500 2. Ratio of mean cube of diameter to mean diameter (units of 0.0001 sq. mm.).  
second figure is omitted, and the values for (3) and (4) are then very rough. Figures in



*Fine Sand.*

Quartz.—As in No. 10.

Plagioclase.—Irregular grains, sometimes cloudy alteration, but usually quite clear and undecomposed.

Augite.—Irregular fragments, usually quite clear.

Iron oxide.—Magnetite or ilmenite. Generally as irregular fragments, more rarely as needles.

Olivine.—Sharp irregular fragments, usually colourless, sometimes showing alteration to iddingsite (typical of the basalt of this area).

Rock.—Fragments of extremely decomposed basalt.

Zircon.—As in No. 10.

Tourmaline.—As in No. 10.

Hyalite and sponge spicules also present.

In the case of these mature soils formed on basalt (Nos. 10-16), very few of the minerals found can have come from the underlying rock. Reference has been made to quartz in basalt (Fenner, 1915), and it is believed that quartz can crystallise from basaltic magma, but the quartz grains which occur in these basaltic soils contain inclusions of apatite, zircon, and rutile, showing that they cannot be authigenic. This is even more clearly the case with the grains of zircon and tourmaline which invariably accompany the quartz. These minerals, therefore, represent foreign material, and they occur also in numerous samples taken on basalt on the plains of the Western District and not described in this paper. This uniform distribution shows that they cannot represent pre-basaltic material picked up by the basalt flows during extrusion.

The occurrence of these minerals appears, therefore, to be due to the addition of wind-blown material to the soil during its formation, and the minerals are, in fact, similar to those which make up the aeolian Quaternary deposits. The total quantity of the foreign material is, however, so small that it would be absurd to say that the soils have not formed from basalt. Pfeiffer and Hellmers (1934) mention the occurrence of quartz in the surface soil of basaltic areas in the Westerwald, Western Germany, and attribute this to the wind. From a formula given by Vageler (1933, p. 148) it appears that the grains in the coarse sand having a diameter of 2 mm. would be moved by a wind blowing at about 33 miles per hour, and those of 1 mm. diameter by a wind of 22 miles per hour. The fine sand particles would, of course, be transported still more easily.

The occurrence of these foreign minerals in the deepest samples taken on basalt appears to be due to the washing of sand down cracks which form in the dry season, associated with the drying of the heavy clay and with root systems. Sand has, in fact, been observed at deep levels in such cracks, in trenches dug in the Birregurra area.

Further evidence of the existence of wind transport is given by the presence, in all Victorian soils examined, of small broken fragments of organic remains, formed of isotropic silica. These have been identified by Mr. F. Chapman as spicules of the fresh water sponge *Spongilla*, in some cases resembling *S. cinerea* Bowerbank. Mr. Chapman states that a lacustrine phase favourable to the development of these organisms occurred in the Kalimnan, but that *Spongilla* is still an abundant living genus in swamp areas. These spicules appear in soils where *Spongilla* could not possibly live at the present time, and they therefore indicate wind transport. They decrease with depth far more rapidly than other wind-blown material, indicating that their addition to the soil was fairly recent, so that they have not had time to mix with the soil to any great extent. The occurrence of sponge spicules, particularly in the surface soil, has been recorded from many localities by Carroll (1931-2 and 1933-4).

These samples of soil taken on basalt indicate the effect of weathering and, for purposes of comparison, an example of an immature basaltic soil is included, from a soil survey of the Mount Gellibrand area near Birregurra (No. 17). The immaturity of this sample is due to erosion on a "stony rise", the slope of the rise causing the removal of the surface soil as fast as it becomes weathered. No. 17 contains large fresh grains of labradorite, augite, olivine, and rock, together with a certain amount of foreign material. It is a dark brown loam and, although very shallow and rocky, is a fertile soil.

On the basalt plains (Nos. 10-15), weathering has gone on to great depth and the unstable basaltic minerals are decomposed, the percentage of silt and clay increasing at the expense of the sand. In the mature basaltic soils the minerals in the sand consist almost entirely of added non-basaltic material, with only a trace of decomposed plagioclase to indicate the parent rock. The result is a grey clay of low fertility, and its chief difference from soils formed from the Quaternary deposits is not in the mineral composition but in the quantity of the coarse and fine sand.

This is well shown by the profile taken at Dixie (Nos. 12-15). This locality was marked as Newer Basalt on the geological map, but no rock was visible, and the profile showed no marked differences from profiles taken on the Quaternary. The influence of basalt is, however, shown by the greater amount and fresher appearance of the plagioclase and by the presence of augite and olivine, both unstable minerals, which are unlikely to survive transport. The high sand percentages, however, indicate that a large amount of foreign material has been added, and the soil may be regarded as intermediate between the normal soils on basalt and those on Quaternary deposits.

This profile indicates also the effect of depth upon the amount and mineral composition of the sand fractions. The fine sand decreases steadily from the surface downwards, owing to the

washing down of clay and the greater amount of wind-blown sand in the surface horizons. (The coarse sand contains buckshot which is most abundant in the B horizon, and this explains the maximum at that level.) The decomposition of minerals may go on at different rates in the different horizons, and has probably gone on for longer in the upper than in the lower levels. This is indicated by the increase in the amount and freshness of fine sand plagioclase as depth increases. The iron oxide, being more stable, does not show this effect. The wind-blown material has been distributed through the soil by washing down cracks, though the sponge spicules are extremely rare in the lower levels.

The minerals of the soil on Older Basalt (No. 16) indicate a still more advanced state of maturity. The felspar grains are decomposed beyond exact identification, and are so small and rare that the sand may be regarded as almost entirely quartz. The comparative fertility of the red loams on these Older Basalts is due to factors which are not connected with the presence of valuable primary minerals.

### **Conclusions.**

It can be seen that the study of soil minerals gives some surprising results. Igneous minerals occur in small quantity in soils derived from Quaternary sands, quartz is the most important mineral in the fine sands of soils formed from basalt, and sponge spicules, zircon and tourmaline are ubiquitous. From these results we may say that purely residual soils are rare, other factors besides the underlying rock being involved in supplying the parent material for any soil, although, in most cases, the added material is of little agricultural importance. The study of the soil minerals is useful in indicating these factors, and also gives valuable information as to the state of maturity of the soil and its probable fertility. The soils studied illustrate the importance of topography in determining the state of maturity of the soil.

### **Acknowledgments.**

This work is in the nature of an introduction to the mineralogical section of a soil survey of the Mount Gellibrand area near Birregurra. It was done under the direction of Professor Skeats and Professor Wadham, whom I wish to thank for their interest and assistance. I would like to thank Miss D. Carroll, of the University of Western Australia, who gave me a great deal of help in the methods of identification of soil minerals. The statistical interpretation of the results obtained is the work of Mr. G. W. Leeper, to whom I am greatly indebted for his continued help and criticism throughout the progress of the work. I would like, also, to thank Miss M. Barnard for the assistance which she has given.



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[PROC. ROY. SOC. VICTORIA, 49 (N.S.), Pt. I., 1936.]

ART. IV.—*A Fossil Casuarina.*

By R. T. PATTON, D.Sc., D.I.C., M.F., F.R.H.S.

[Read 14th May, 1936; issued separately, 23rd November, 1936.]

The records of the genus *Casuarina*, one of the characteristic genera of Australian vegetation, occurring as fossils are very sparse and they are not entirely free from doubt. Deane (1904), speaking of the Sentinel Rock specimen, says "probably *Casuarina*." The identification is exceedingly doubtful. Chapman (1914) matches an impression in some newer basalt at Yandoit with that made by the end of a cone of *Casuarina stricta*. It may be referable to *Casuarina* but the evidence is very slender.

Paterson (1935) recognizes a *Casuarina* from some longitudinally ridged "branchlets," 4 mm. wide, with internodes 2 mm. long.

Engler and Prantl (1889) remark that the fossils from the Eocene in Europe referred to *Casuarina* are insufficiently established, and are possibly referable to *Ephedra*.

Very well preserved wood remains of *Casuarina* have been found under the newer basalt, and have been discussed by Chapman (1905) and Armytage (1910).

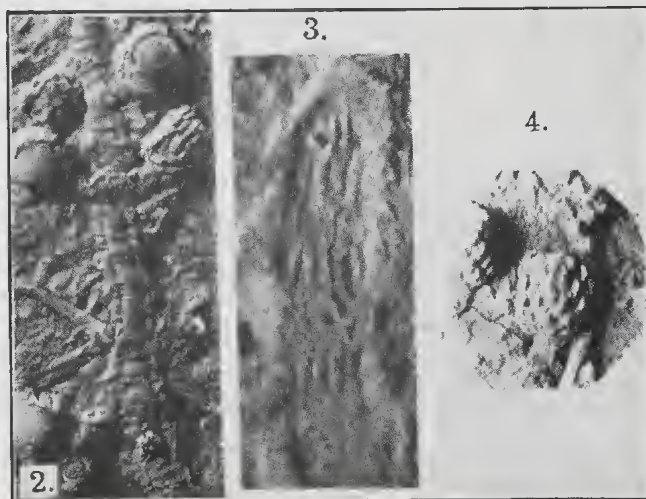
Excellent impressions of a *Casuarina* have been found in a siliceous sandstone at Limestone Reserve, Parish of Yallock. The beds in which the impressions occur are possibly of Miocene age. They overlie Lignites which are Oligocene. The impressions are beautifully preserved, even the tips of the branchlets showing up quite clearly on plasticene casts. The branchlets are finely ridged, 1.5 mm. broad and the rudimentary leaves, which are so characteristic a feature of *Casuarina*, are acute, 10 to 12, possibly only 10, in a whorl. The branches show the scars where rudimentary leaves originally occurred. The cones are 7-8 mm. long, subglobose to subcylindrical, truncate, tapering towards the ends. The valves are obtuse, very prominent and in several rows, but the keel is obscure. There is no sign of any male inflorescence nor of seed.

Both on account of the number of teeth and the size of the cones the specimen is allied to the Victorian species *Casuarina glauca* Sieb., which at present occurs in the north-west of the State, and also to *C. Cunninghamiana* Miq. which is quite commonly found along river banks in the eastern portion of New South Wales.





1.



A Fossil Casuarina.

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### **Explanation of Plate I.**

1. Photograph of original impressions, slightly less than  $\frac{1}{2}$  nat. size.
2. Photograph of a plasticene cast of a branch, approx. nat size.
3. Photograph of plasticene cast of the end of a branchlet,  $\times 6$ .
4. Photograph of a plasticene cast of a cone, slightly enlarged.

[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. I., 1936.]

ART. V.—*On the Occurrence of Almandine Garnets in Some Devonian Igneous Rocks of Victoria.*

By A. B. EDWARDS, Ph.D., D.I.C.

[Read 11th June, 1936; issued separately, 23rd November, 1936.]

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### Introduction.

Attention was first drawn to the widespread occurrence of pink garnets in the Devonian igneous rocks of Victoria by Dr. N. R. Junner (1), in 1914, but with the few facts at his disposal he preferred not to advance any hypothesis as to their origin.

Investigation has shown that the garnets are characteristic of the rhyodacites, and of certain of the associated porphyries, rhyolites and hypabyssal rocks. No garnet has been observed in any of the hypersthene-dacites (andesites), but at Warburton a small patch of garnet-anthophyllite rock has developed where the hypersthene-dacite has been intruded by granodiorite (2). Garnets of similar character to those in the rhyodacites have also been observed in some of the granodiorites associated with these lavas.

### Composition of the Garnets.

Approximate chemical analyses, shown in Table 1, were made of small hand-picked specimens of garnet from several sources. They indicate that the garnets are of relatively similar composition, consisting of almandine, with varying, but minor, proportions of pyrope, andradite, and spessartite.



TABLE 1.—ANALYSES OF GARNETS.

—			1.	2.	3.	4.	5.	6.
			%	%	%	%	%	%
SiO <sub>2</sub>	..	..	34.5	35.0	34.8	34.7	36.4	32.8
Al <sub>2</sub> O <sub>3</sub>	..	..	23.1	19.8	21.2	18.5	21.4	20.3
FeO*	..	..	39.4	34.2	36.0	36.6	32.1	40.0
MgO	..	..	0.5	5.1	4.8	5.4	7.7	2.4
CaO	..	..	1.9	3.5	1.8	2.7	1.7	1.4
MnO <sub>2</sub>	..	..	1.5	2.3	1.6	2.3	1.5	3.2
TiO <sub>2</sub>	..	..	nil	nil	nil	nil	nil	nil
P <sub>2</sub> O <sub>5</sub>	..	..	tr.	tr.	tr.	0.5	tr.	0.2
			100.9	99.9	100.2	100.7	100.8	100.3

\* FeO = total iron.

1. Garnet from quartz-dacite (rhyodacite) sill, Porphyry Peak, near Mansfield.
2. Garnet from a coarse patch of quartz-biotite-dacite (rhyodacite) near Devil's Elbow, Black's Spur, near Fernshaw.
3. Garnet from quartz-biotite-dacite (rhyodacite), Strathbogie Ranges.
4. Garnet from granodiorite-porphyry, dyke or sill, Taggerty.
5. Garnet from granite-porphyry or orthoclase-porphyry, Mt. Taylor, Eastern Gippsland.
6. Garnet from a contaminated block of granodiorite, Maroonah Dam Tunnel dump, near Donnelly's Weir, Healesville.

Analyst—A. B. EDWARDS.

### Garnets in the Rhyodacites

The pink garnets are characteristic of the rhyodacites and such associated rocks as are of relatively similar mineralogical composition, e.g., biotite-rich rhyolites.

The garnets exist either (1) as stable garnets in a state of arrested growth, or (2) as unstable garnets in a state of partial resorption.

#### (1) STABLE GARNETS.

Stable garnets are typically developed in the quartz-dacite sill, or flow, at Porphyry Peak, near Mansfield. As illustrated in Fig. 1, they occur as somewhat inchoate idiomorphic crystals. The finely crenulated periphery, and the embayments about partially enclosed iron ore grains, which are unable to enter into the composition of their host, indicate that the growth of the garnets was arrested by the crystallization of the lava. Such garnets are invariably surrounded by a rim of partially or completely sericitized felspar, which consists of hypidiomorphic crystals of orthoclase and albite-oligoclase, growing in columnar fashion outwards from the garnet. The width of these felspar rims corresponds more or less to the size of the garnet crystals which they accompany, indicating that it is "reject matter" from the magma and crystalline material out of which the garnet was formed, and that it was thrust outwards by the growing garnet.

A similar feature has been described associated with garnets in the Hooper Mine, United States of America (3). Small quantities of similar felspar accompany the numerous inclusions of iron ore and apatite which are generally present in the garnets.



FIG. 1.—Garnet in a state of arrested growth, showing felspar rim. From rhyodacite of Porphyry Peak. The inclusions consist of iron oxides (black), and epidote and zircon grains (cross hatched). The fracture at the bottom is partially filled with chlorite.

These inclusions represent instances in which “embayments,” referred to above, have been closed round un-assimilated material while the garnet was still growing freely.

So long as the lavas did not undergo differential movements during their period of consolidation, the rims have remained intact, as in the Porphyry Peak sill; but where differential flowage has occurred during the crystallization of the lava, the garnets are frequently shattered, and the rims are often partially torn away.

The garnets in the Porphyry Peak rock contain inclusions of chloritized biotite, iron ore grains, numerous small zircons, and

grains of epidote (?). Identical zircons and epidotes (?) occur throughout the biotite crystals of the rock, and in the groundmass where they may be derived from the breakdown of the biotite phenocrysts which is in progress. The iron ore grains and the epidotes (?) appear to have been precipitated from the biotite during its chloritization. In the garnet they are enclosed in minute areas of potash feldspar, into which a number of zircon crystals are often crowded. Concentrations of zircons and grains of epidote (?) are also found in the feldspar rims, which seems to support the suggestion that these are "reject matter" pushed aside by the growing garnets.

Garnets of this type from other localities are identical, except that the place of the zircon inclusions is frequently taken by apatite, if apatite is the common inclusion of the feldspar or biotite phenocrysts in the rocks which contain the garnets.

In the granite-porphyry of Mt. Taylor (analysed garnet No. 5) large idiomorphic garnets, up to 1 cm. in diameter, occur in the groundmass, while much smaller garnets frequently serve as a nucleus to the large orthoclase phenocrysts which characterize the rock. In this instance the larger garnets and the orthoclase crystals must have crystallized contemporaneously.

## (2) UNSTABLE GARNETS.

In some lavas, especially the rhyodacites on the Black's Spur, Marysville, and Strathbogie Ranges (analysed garnets Nos. 2 and 3), the originally idiomorphic garnets are no longer in equilibrium with the magma, and have been preserved in a partially resorbed state. Remnants of a feldspar rim are frequently present. In the Marysville rhyodacites the resorption of the garnets is almost complete, and the final remnants of the garnet are reacting to form biotite (4).

This is also the case at Taggerty (4), where corroded and vermiculate remnants of garnet are observed with clusters of fine biotite flakes about their rims.

In each instance, where there is a clue to the origin of the garnet, either from included minerals or reaction remnants, the garnet appears to have developed from a reaction between previously crystallized ferromagnesian minerals, and either plagioclase crystals or the magma.

At Porphyry Peak the reaction appears to have been—

magma + plagioclase + biotite  $\rightarrow$  garnet + orthoclase + iron ore and albite-oligoclase.

In other instances, as at the Black's Spur (analysed garnet No. 2), the reaction appears to be—

magma + plagioclase + hypersthene  $\rightarrow$  garnet + orthoclase and albite-oligoclase.

## Granitic Rocks.

### GARNETS IN THE GRANODIORITES.

Garnet is a rare mineral in the granodiorites associated with the dacite and rhyodacite lavas, and in granitic rocks in Victoria generally. When it is present it occurs as a reaction product of contamination, generally in association with partially assimilated ferromagnesian-rich xenoliths.



FIG. 2.—Xenolith in granodiorite from Maroondah Dam Tunnel dump. Garnets growing around the rim of the xenolith and in the "strew."

A most instructive specimen was found in the dump from the Maroondah Dam tunnel, near Donnelly's Weir, Healesville (5). The specimen is illustrated in Fig. 2. It is a partially granitized xenolith enclosed in granodiorite. The xenolith consists of two zones:—(1) a core which has been re-crystallized but not granitized, and (2) an outer granitized zone. The core zone consists of micro-porphyroblasts of hypersthene and schillerized poecilitic plates of labradorite, set in a trachytic textured base of plagioclase, quartz and granular pyroxene, and shows an abrupt contact with the granitized zone, in which large porphyroblasts of labradorite have developed, and the hypersthene crystals have been altered completely to biotite. There has been an introduction of quartz which is intergrown with felspar, now greatly calcitized and sericitized. The presence of pyrrhotite and the carbonates points to mineralization during re-crystallization. Portions of this outer zone have been "rafted off" into the magma, becoming disseminated as they floated away from the xenolith.



Numerous pink garnets, as large as 0.5 cm. in diameter, occur in a state of arrested growth at the contact of the outer rim of the granitized zone of the xenolith and the granodiorite, and similar garnets are observed accompanying the clots of biotite which are floating away into the granodiorite (Fig. 2).

These garnets are identical in most respects with the "stable garnets" of the rhyodacites. They have a more irregular outline, and are surrounded by a rim of sericitized feldspar, in which are concentrated numerous crystals of apatite and zircon. Similar apatite and zircons, and rare grains of rutile are included within the garnets, together with small remnants of biotite and small areas of altered feldspar. The apatite and zircon are obviously derived from the feldspar and biotite of the xenolith during their reaction to form garnet. The potash and soda of the biotite and plagioclase has formed the orthoclase and albite of the rim, and this together with many of the not easily assimilated former inclusions has been pushed aside by the growing garnets into a rim. The embayment of the rim of the garnet arises from its inability to assimilate particles of iron ore. Generally it grows round these obstacles, but the onset of crystallization in the rock has preserved the rim in an inchoate state.

A specimen of granodiorite from Braemar House, Macedon, shows a similar development of pink garnet at the contact of a partially assimilated basic clot, consisting of biotite and hypersthene. The garnets carried numerous minute inclusions of iron ore, sometimes associated with feldspar and chloritized remnants of biotite. Similar developments of garnets at the contact of basic inclusions in granitic rocks have been observed at South Morang, and by Tattam (6) at Bulla.

As the garnets become parted from the basic clots by dissemination of the latter through the granite, they lose their stability, and tend to re-dissolve in the magma. This corresponds with the behaviour of the garnets in the rhyodacites.

### **Garnet in Contact Zones of Dacite and Granodiorite.**

In the contact zone of the hypersthene-dacite and granodiorite at Warburton, a small patch of garnet-anthophyllite rock has been found (2), apparently developed from the dacite by recrystallization. The garnet forms lens-shaped poeciloblasts, and appears to have arisen from a reaction between the plagioclase and the anthophyllite or biotite of the rock, since they develop at the contact of plagioclase porphyroblasts and sheaves of anthophyllite. It is somewhat paler in colour than the pink to red garnets of the lavas and granitic rocks, and is probably richer in magnesia. It is so disseminated throughout the rock and so filled with inclusions of anthophyllite that no useful analysis could be obtained.

## Products.

### ALTERATION OF THE GARNETS.

The garnets in the rhyo-dacites may alter to several distinct minerals:

#### 1. *Alteration to Penninite.*

Most commonly the garnets alter to a bright green penninite, with deep ultra-blue polarisation colours, indicating that it is an iron-rich chlorite. The alteration seems to be almost purely a hydration.

Garnet.

Penninite.



#### 2. *Alteration to Biotite.*

This alteration, which has been observed previously by both Junner (1) and Hills (4), represents a reversal of the process of formation; but whereas in the formation of the garnet there was an excess of ferromagnesian molecules requiring to be saturated with silica, there is now an excess of silica requiring that the available ferromagnesians be more widely shared.

#### 3. *Alteration to Cordierite.*

In several instances Dr. Hills has observed the alteration of garnet to cordierite. As in the formation of secondary biotite, the garnet apparently becomes unstable with the increase of available "free silica," and alters to cordierite, whereby the same amount of ferromagnesian molecules is shared with a larger amount of silica.

Garnet.

Cordierite.



The FeO:MgO ratio must exceed unity for such cordierite, a possibility which has been stressed by Harker (7), who considers that there is probably no limit to the ratio.

This reaction may account for the decrease in the number of garnets and the increase in cordierite trillings as the lavas grow more acid, viz. in the rhyolites and more acid rhyodacites. No cordierite trillings are found in the hypersthene-dacites.

## Origin of the Garnets.

Junner (1) was unable to decide whether the garnets were of pyrogenetic origin, or whether they were products of contamination. It is now clear that the garnets in the granitic rocks are products of contamination, derived from the partial assimilation of iron-rich micaceous sediments, such as shales. The garnets of the rhyodacites, however, are too characteristic, numerous, and widespread to be easily explained in this manner, unless the rhyodacites (and their associated lavas) are regarded as syntectics, rather than as true lavas.



Examination of Table 2 shows that the garnets are restricted to those varieties of lava in which quartz occurs as phenocrysts, accompanied by a relatively large amount of ferromagnesian minerals. No garnet has ever been observed in the lavas which have no quartz phenocrysts, e.g., the hypersthene-dacites, felspar porphyrites, and andesites. This association of garnet with quartz phenocrysts indicates that, before the garnet can develop, the magma must have reached a state of "silica saturation" beyond the requirements of the normal ferromagnesian minerals (biotite,

TABLE 2.

Rock.	Garnet.		Phenocrysts.					
			Qz.	Bi.	Hy.	Hb.	Or.	AbAn.
<i>Narbethong—</i>								
Rhyolite .. ..	..	..	×					×
Quartz-dacite .. ..	..	×	×	×				×
Quartz-biotite-dacite .. ..	..	×	×	×				×
Quar.-bio.-hyp.-dacite .. ..	..	×	×	×	×			×
Granodiorite porphyry .. ..	..	×	×	×				×
Hypersthene-dacite .. ..	..			×	×			×
Andesite .. ..	..				×			×
<i>Marysville—</i>								
Toscanite .. ..	..	×	×	×				×
Nevadite .. ..	..		×					×
Dacite .. ..	..	×	×	×				×
Andesite .. ..	..				×			×
<i>Taggerty—</i>								
Rhyolite .. ..	..	×	×	×				×
Granodiorite-porphyry .. ..	..	×	×	×				×
<i>Mansfield—</i>								
Rhyolite .. ..	..	×	×	×				×
Quartz-dacite .. ..	..	×	×	×				×
<i>Dandenong Ranges—</i>								
Toscanite .. ..	..							×
Quartz-dacite .. ..	..	×	×	×				×
Quartz-biotite-dacite .. ..	..	×	×	×				×
Hypersthene-dacite .. ..	..			×	×			×
Hornblende-porphyry .. ..	..					×		×
<i>Warburton—</i>								
Rhyolite .. ..	..		×					×
Quartz-biotite-dacite .. ..	..	×	×	×				×
Hypersthene-dacite .. ..	..			×	×			×
Felspar-porphyrite .. ..	..					×		×
Andesite .. ..	..				×			×
<i>Strathbogie—</i>								
Quar.-bio.-hyp.-dacite .. ..	..	×	×	×	×			×
<i>Mt. Taylor—</i>								
Orthoclase-porphyry .. ..	..	×	×	×				×
<i>Macedon—</i>								
Hypersthene-dacite .. ..	..				×			×

## Explanation—

Qz.	=	Quartz.
Bi.	=	Biotite.
Hy.	=	Hypersthene.
Hb.	=	Hornblende.
Or.	=	Orthoclase.
AbAn	=	Plagioclase.

hypersthene or hornblende) and the feldspars. It is also clear that, irrespective of the exact crystal form which they take, the concentration of the crystallized ferromagnesian must exceed a certain minimum. If the proportion of ferromagnesian minerals dwindles below this minimum, the garnets become unstable and dissolve or break down into more stable forms, in which the ferric molecules are shared with a greater number of silica molecules than is possible in garnet. Thus garnets are found only in such rhyolites as possess phenocrysts of ferromagnesian minerals, and, even then, have always entered upon unstable conditions. Similarly, the garnets in the granites are found only in association with local concentrations of ferric material, and become unstable as soon as the ferric concentration is disseminated by further assimilation.

In the hypersthene-dacites the requisite amount of ferromagnesian was present, but there was no "free silica," and hence no garnet. Where, however, such a hypersthene-dacite has been recrystallized by granodiorite under favorable conditions, probably determined by a combination of pressure and temperature, garnet has formed, the quartz of the groundmass, which was not available in the lava state, providing the "free silica."

The development of garnet, therefore, marks a distinct stage in the crystallization differentiation of these lavas—a stage characterized by the development of "free silica" in the magma, and the retention of a certain concentration of crystallized ferromagnesian minerals. The maximum concentration of garnet occurs when about 50 per cent. of the magma has crystallized, as indicated by the following micrometric analyses:—

				1.	2.	3.
				%	%	%
<i>Phenocrysts —</i>						
Quartz..	..	..	..	13.2	11.5	15.5
Biotite, &c.	..	..	..	10.5	15.5	10.5
Feldspars	..	..	..	28.9	27.0	18.3
<i>Groundmass</i>	..	..	..	47.4	46.0	55.7

1. Rhyodacite (or quartz-hypersthene-biotite-dacite), Bladin's Quarry, top of Black's Spur.

2. Rhyodacite (or quartz-biotite-dacite), midway up the Black's Spur.

3. Rhyodacite (or quartz-dacite) from Porphyry Peak, near Mansfield.

As crystallization advances with further magmatic cooling, the ratio of Free Silica to Ferromagnesian increases, and the garnets become unstable. Accordingly, in acid plutonic rocks, granites and granodiorites, garnet is an exceptional mineral. The garnet is only preserved if extrusion occurs to "freeze" the magma before further crystallization takes place.

Viewed in this light, the garnet appears to be a true "discontinuous reaction" mineral (8), but it also tends to be "syntectic" (9), developing mainly from interaction between previously crystallized minerals. The effect of assimilation would only hurry the process if it introduced silica to the magma, or prolong it if it introduced ferromagnesians. The rhyolites, the various rhyodacites, and the hypersthene-dacites have all assimilated Silurian shales and sandstones, but garnets are absent from the hypersthene-dacites, and, commonly, from the rhyolites. Moreover, as the rhyodacites become more acid, the amount of garnet in them correspondingly decreases. Assimilation of similar sediments to at least equal degree in the granodiorites and granites has only served to prolong the garnetiferous stage sporadically in them.

If, as indicated, the garnets are pyrogenetic, then garnetiferous rhyodacites should be a frequent (and characteristic?) feature of andesite-rhyolite suites; and in this respect it may be noted that the development of almandine garnets in rocks of this type is not uncommon. The author has observed them in specimens of relatively similar dacitic types from New Zealand, Italy, and Hungary, and Iddings (10) refers to almandine garnet as occurring in granites and some andesites.

The development of garnets in such lavas obviously occurs at a late stage in the cooling history of the magma, and previous to extrusion. Frequently it is brought to a close by the sudden increase of viscosity accompanying extrusion. It is often later than, or accompanied by, such deuteric phenomena as chloritization of biotite or hornblende, and the introduction of sulphide minerals; and where there has been a concentration of mineralisers, as in some pockets of coarser rock in the Black's Spur rhyo-dacite, the reduced viscosity of the magma has permitted the garnets to become more numerous and larger than usual.

### Summary.

Almandine garnets of pyrogenetic origin are characteristic of the Upper Devonian rhyodacites of Victoria, and some associated rhyolites and hypabyssal rocks. They developed at a late period in the cooling of the lavas, at a stage when the ferromagnesians were still fairly concentrated, but silica was crystallizing in excess of the needs of both ferromagnesians and feldspars. With diminution of the ferric content of the lavas they become unstable and re-dissolved.

Similar garnets occur sporadically in associated granitic rocks, in association with partially assimilated basic clots. With dissemination of the basic clots these garnets also become unstable.

The unstable garnets may merely dissolve, or they may alter to penninite, secondary biotite, or to iron-rich cordierite.

Similar garnetiferous rhyodacites should characterize other andesite-rhyolite suites.

### Acknowledgments.

In conclusion, I wish to thank the staff of the Geology Department and the Curator of the Geological Survey Museum for help in obtaining specimens for analysis, and Professor Skeats for permission to make the analyses in the departmental laboratory.

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ART. VI.—*Additions to the Australian Ascomycetes, No. 3.*

By ETHEL McLENNAN and FRANCES HALSEY.

[Read 11th June, 1936; issued separately, 23rd November, 1936.]

### Introduction.

Since the issue of the last paper in this series (1926), a monograph of the North American Cup Fungi (Operculates) has been published by Seaver (1928). It contains many excellent descriptions and photographs of these Discomycetes. The authors of this paper, however, have not followed the nomenclature adopted by Seaver, for it is based on the rules of the American Code which are not in accord with the International Rules of Botanical Nomenclature.

To be in unison with the British mycologists (Ramsbottom, 1913), and to refrain from adding any further confusion to an already chaotic field, we have followed the arrangement given by Boudier in his "Histoire et Classification des Discomycètes d'Europe" (1907) as this is the course suggested to us in correspondence with Sir Arthur Hill, who writes—"It would be better to follow Boudier for the present, as do most European mycologists, although Boudier's nomenclature is also not always in accordance with Rules. Until there is an agreed list of *Nomina generica conservanda*, with type or standard species, for fungi, it is inadvisable to attempt to alter names in fairly general use."

The other contributors to the systematics of Australian Discomycetes have been Cooke (1892) and Rodway (1924). Each of these workers has followed different authorities in deciding on the nomenclature of their recorded and newly described forms, so where necessary synonymy will be included to render it easy to trace the history of the forms already on record for Australia.

All colour notes have been made using Ridgway (1912) as a standard.

### ALEURIEAE.

#### **Aleuria**

##### (a) *Levisporcs.*

ALEURIA DOMICILIANA (Cooke) McL. and H. (nov. comb.).

Apothecia gregarious, stipitate, concave when young, soon becoming strongly repand, with a depression in the region of the stem, at first rounded, mature specimens often becoming angular

in outline, from 1.5–10 cm. in diameter, stem up to 1 cm. in length, 0.5 cm. broad; externally white, hymenium clay colour to tawny olive; asci cylindrical, blue with iodine; spores ellipsoid, hyaline, smooth,  $8-10.5 \times 14-18\mu$ ; paraphyses slender, septate, enlarging above.

Recorded for Victoria, Australia, for the first time; the specimens were found growing in a cask near Melbourne in July, 1935. Collected by Miss G. Fawcett.

Seaver (1928) records specimens found in cellars, mushroom caves, and occasionally in greenhouses, usually growing on plaster, sand, gravel, or coal dust.

Type Locality.—Scotland.

Distribution.—North America, Europe, and Australia (Victoria).

#### ALEURIA REPANDA (Pers.) Gill.

Apothecia repand, very short stipitate, externally whitish, mealy, 3–6 cm. in diameter; hymenium cinnamon brown, margin more or less entire; stem short, stout, usually only a few mms. long, more like a rooting base, or wanting; asci cylindrical, blue with iodine; spores ellipsoid, mostly non-guttulate, smooth, hyaline,  $8.6-12 \times 15-18\mu$ ; paraphyses not numerous, slender, septate, branched, with conspicuously swollen apices.

First recorded for Australia by Cooke (1892) as *Discina repanda* Wahl., on rotten trunks and the ground, Victoria and New South Wales, and for Tasmania by Rodway (1924) as *Peziza repanda* Wahl. (*Discina repanda*, Fries.). Redescribed above from specimens on wood collected at Warrandyte, Apollo Bay and Fern Tree Gully, Victoria, from July to September, 1935.

Type Locality.—Europe.

Distribution.—North America, Europe, Australia (Victoria, New South Wales, Queensland, and Tasmania).

#### ALEURIA VIOLACEA (Pers.) Gill.

Apothecia sessile, occasionally substipitate, shallow cup-shaped, discoid, or repand, regular when young, becoming irregular when old; hymenium concave, plane or convex, dark vinaceous-drab, sometimes becoming Dresden brown to raw umber, externally whitish but with a purplish tinge, 1.5–5.5 cm. in diameter; asci cylindrical, 8-spored, blue with iodine; spores usually 1-seriate, ellipsoid, faintly bi-guttulate, hyaline, smooth,  $7-8 \times 11-13\mu$ , paraphyses slender, septate, enlarged above, curved, usually reaching a diameter of  $6\mu$  at the apices, coloured brown, becoming yellow towards the base.



Boudier (1907) recognizes *Aleuria violacea* (Pers.) Gill., but in his definition of the genus he describes the spores as non-guttulate. The Australian specimens examined by us have always shown bi-guttulate spores, and in this feature appear exceptional.

On ashes or burnt ground, Lorne, Apollo Bay and Balnarring, Victoria, May to September, the first record for Australia.

Type Locality.—Europe.

Distribution.—North America, Germany, Finland, Australia (Victoria).

(b) *Verrucisporas*.

*ALEURIA APICULATA* (Cooke) Boud.

Apothecia sessile, scattered, cup-shaped to discoid, fleshy, margin entire, up to 3 cm. in diameter; hymenium mummy brown, concave; asci cylindrical, blue with iodine, 8-spored; spores oblong-ellipsoid, pale brown, delicately sculptured with minute warts, often with a small apiculus at each end,  $8.5-12 \times 21-25.5\mu$ ; paraphyses filiform, septate, often adhering together, brown.

First recorded for Australia (Victoria) by Cooke (1892), on bark, as *Peziza* (*Phaeopezia*) *apiculata* Cooke. The above description is based on specimens growing on soil, collected at Macedon, Victoria, in October, 1931.

Type Locality.—Italy.

Distribution.—North America, Europe, Australia (Victoria).

*SARCOSPHAERA FUNERATA* (Cooke) Seaver.

Apothecia scattered, entirely immersed in sand, globose, at first closed, then at maturity bursting above into several lobes in a Geaster-like manner, reaching a diameter of 2 cm., broadly stipitate, stems up to 2 cm. in length, spreading out at the base in a root-like fashion, externally clothed with a mass of entangled hyphae to which the sand particles adhere; hymenium auburn; asci turning blue with iodine, 8-spored; spores broadly elliptic, smooth, hyaline, thick walled, thicker at the ends,  $13-18 \times 23.5-29\mu$ ; paraphyses clavate, slightly curved at the apices, septate and moniliform.

In sandy soil.

The specimens from which the above description was made were collected on a hillside in the Wyperfeld National Reserve, Victoria, Australia, by Mr. R. Croll, in October, 1935.

Type Locality.—Florida.

Distribution.—North America, Australia (Victoria, South Australia, and Tasmania).

*Sarcosphaera funerata* (Cooke) Seaver was recorded from South Australia in 1885, as *Peziza fumerata* Cooke, Clarendon, 1882. This record was in name only (Tepper, 1885). The specific name was incorrectly spelt.

Rodway (1924) recorded a new species of *Sepultaria* for Tasmania from Bellerive, which he named *S. austro-geaster*. Type material of this form was obtained from the Tasmanian museum through the courtesy of the Director, Dr. Joseph Pearson, and examination showed it to be identical with the older species, *Sarcosphaera funerata*.

From a note accompanying Rodway's type material, apparently another collection of his form was made at Mount Nelson Range. The spore measurements given in the published account of the Bellerive material are  $10 \times 24\mu$ , but after examination of further material from Mount Nelson Range, Rodway gives the spore measurements in a note on the outside of the packet as  $10 \times 24-28\mu$ .

Although *Sarcosphaera funerata* was recorded for South Australia as *Peziza fumerata* Cooke in 1885, in name only, this is the first record for Victoria, and detailed description of the form for Australia, under the name *Sarcosphaera funerata*.

#### PEZIZEAE.

##### PUSTULARIA CUPULARIS (Linn.) Fuck.

Apothecia gregarious, briefly stipitate, slender, globose, reaching a diameter of 0.3 cm.-1 cm., margin crenated, externally mealy, Dresden brown, internally tawny-olive, plant resembling a small acorn cup; stem short, from 2-3 mm. long and about 1 mm. thick, expanding abruptly into the apothecium; hymenium concave; asci cylindrical, not coloured blue with iodine; spores 1-seriate, hyaline, smooth, bi-guttulate,  $10-12 \times 18-20\mu$ ; paraphyses hyaline, septated, slightly enlarged above.

On the ground, Warrandyte, Victoria, Australia, July, 1935. First record for Australia.

Type Locality.—Europe.

Distribution.—North America, Europe, Australia (Victoria).

##### PEZIZA AURANTIA Pers.

Apothecia gregarious, from 0.5-6 cm. in diameter, cups shallow when young, quite flat when older, often somewhat contorted, may be Otidea-like occasionally, externally whitish pruinose; hymenium when young scarlet to grenadine red, larger and older specimens orange chrome; asci cylindric, not turning blue with iodine; spores 1-seriate, arranged obliquely in the ascus, at first smooth with two oil drops, but soon becoming sculptured,  $8-10 \times 15-22\mu$ ; spore ornamentation in form of reticulations which are regular and shallow, the ridges often projecting at the

ends, giving rise to apiculi; reticulations  $2-3\mu$  across spaces; paraphyses abruptly enlarged at apices, filled with orange granules, turn green with iodine.

On soil. First recorded for Australia by Cooke (1882), from Victoria, New South Wales, and Tasmania, and by Rodway (1924) for Tasmania. The above description is a more detailed account of the species.

Type Locality.—Europe.

Distribution.—North America, Europe, Australia (Victoria, New South Wales, and Tasmania).

PEZIZA RHENANA Fuck.

Apothecia caespitose, usually 1–2 cm. in diameter, stipitate, externally whitish, tomentose; stem variable in length, up to 2 cm.; hymenium concave, Mars orange; asci cylindrical, not coloured with iodine, possessing stem-like base; spores ellipsoid, hyaline, bi-guttulate, at first smooth, then sculptured,  $9-12 \times 19-22\mu$ ; spore sculpturing consisting of reticulations, the ridges extending beyond the periphery of the spore; paraphyses filiform, filled with orange granules, green with iodine.

On soil. First recorded for Australia by Cooke (1892), from West Australia, as *Sarcoscypha rhenana* (Fuck.) Sacc. The above description is based on material collected at Macedon, Victoria, July, 1935.

Type Locality.—Europe.

Distribution.—North America, Europe, Australia (Western Australia and Victoria).

URNULA CAMPYLOSPORA (Berk.) Cooke.

Apothecia infundibuliform, black, up to 2.5 cm. broad, shortly or elongated stipitate, tough, externally fibrillose, deeply or irregularly rugose, margin incurved, stem even or sulcate, 1–2 cm. long, asci cylindrical, not blue with iodine; ascospores curved, rounded at the ends,  $10-13 \times 23-32\mu$ ; paraphyses slender, branched, frequently bent at the apices.

On decaying wood, recorded for Queensland and New Zealand by Cooke (1892), for New South Wales by Cleland and Chee (1917) (1919), and for Tasmania by Rodway (1924), but this is the first record of the fungus for Victoria; specimens were collected at Yallourn in June, 1929, and at Mount Sabine (Otway Ranges) in May, 1936.

Type Locality.—New Zealand.

Distribution.—New Zealand, Australia (Queensland, Victoria, New South Wales).

## LACHNEA VINOSO-BRUNNEA (B. &amp; Br.) Sacc.

Apothecia sessile to short stipitate, gregarious, concave when young, becoming more flattened when older, sometimes with crenated margins, externally pale; pinkish buff, darker when young, clothed with short blunt, thick walled, septated hairs, giving the surface a furfuraceous appearance; hymenium burnt umber; asci cylindrical, not coloured blue with iodine; spores 8, ovoid hyaline, non-guttulate, with conspicuous gelatinous coats, finely sculptured when mature,  $15-20 \times 23-28\mu$ ; paraphyses slightly clavate, septate, yellowish brown.

First recorded on burnt ground by Cooke (1892) for Queensland, Australia, as *Lachnea vinoso-brunnea* B. & Br., and is now described more fully from specimens collected in Victoria from Heathmont, Kallista, and Eltham in November, 1934-1935.

Type Locality.—Australia (Queensland).

Distribution.—Australia (Queensland, Victoria).

## CILIAREAE.

CILIARIA SCUTELLATA (L.) Quél.  
1907.

Apothecia gregarious, sessile, 2-6 mm. in diameter, globose and closed when young, appearing dark brown from the external covering of hairs, expanding and becoming discoid at maturity, with the margin slightly raised and fringed with conspicuous brown hairs; hymenium English red to burnt sienna; hairs with rooting bases, gradually tapering to bristle-like apices, up to 2 mm. in length, thick walled, septate; asci cylindrical, not coloured blue with iodine; spores 8, elliptical, smooth, filled with oil drops,  $11.5-13.3 \times 16.8-20\mu$ ; paraphyses strongly enlarged above, reaching a diameter of  $7-9\mu$  at their apices.

First recorded on rotten wood by Cooke (1892) for Victoria, Queensland, New South Wales, Western Australia, and Tasmania, as *Lachnea (Scutellinia) scutellata* L., and has less frequently been found growing on soil in Victoria since then. Recorded by Rodway (1924) for Tasmania as *Lachnea scutellata* Gill.

Type Locality.—Europe.

Distribution.—North America, Europe, Australia (Victoria, Western Australia, Queensland, New South Wales, and Tasmania).

## NEOTIELLA CATHARINAEA sp. nov.

Apothecia solitaria, disciformi, modo sessili modo breviter stipitata, 4-5 cm. in diam., extrinsecus capillacea. Hymenio "capucine yellow to orange." Ascis cylindricis, cum iodino haud

caeruleis. Sporis octo, ellipsoid., hyalinis, reticulatis, bi-guttulatis,  $23-26 \times 13-16\mu$ . Paraphysibus septatis, ramulatis, granulorum aurantiacorum ad apices refertis.

In axillis foliorum plantae musci *Catharinaea Mülleri* Hamp. et C. Müll.

Apothecia usually solitary, sub-globose when young, very minute, gradually expanding until disc-shaped at maturity, sessile to very short stipitate, reaching 4-5 mm. in diameter, externally clothed with white downy hairs; hymenium plane, sometimes convex, capucine yellow to orange, surrounded by a delicate fringe of hyaline (white to the naked eye) hairs; asci cylindrical, operculate, not coloured blue with iodine; spores 8, ellipsoid, hyaline, uniseriate, with ends slightly over-lapping, reticulate, usually bi-guttulate,  $13-16 \times 23-26\mu$ ; paraphyses slightly enlarged above, projecting beyond the ripe asci, septate, branched, densely filled with minute orange granules at their apices.

On the moss plant *Catharinaea Mülleri* Hamp. et C. Müll., apothecia occurring in the axils of the leaves. Collected at Kallista and Ferntree Gully, Victoria, from September to December, 1925-1934.

Type Locality.—Kallista, Victoria.

Distribution.—Australia (Victoria).

The apothecia are situated in the axils of the leaves and a longitudinal section through a plant shows a mass of entangled hyphae at the base, which appears to act as an anchor. (Plate I., Fig. 6.) When cut transversely in the same region this mass of hyphae is seen to extend around the moss stem externally, as a band of coarse interwoven hyphae.

The hyphae towards the outer surface of the fruit body are arranged in a pseudo-parenchymatic manner and form a well-defined exciple. (Plate I., Fig. 6.) The entire outer surface is densely clothed with thick walled septated hairs of varying lengths, usually unbranched, but sometimes branched (Plate I., Fig. 4A), varying from  $6-9\mu$  in diameter and gradually tapering towards their blunt apices (Plate I., Fig. 4B). At the margin of the exciple the hairs form a fringe around the hymenium; this is diagrammatically represented in Plate I., Fig. 5.

In the young ascus the spores contain smaller and more numerous oil drops, and entirely lack reticulate thickening; they are uniseriate but are situated close together at the top of the ascus. As the spores mature the oil is collected into one or two large drops, the reticulations appear, and the spores extend further down into the ascus. (Plate I., Fig. 2.) The paraphyses slightly exceed the asci, they are septated, and branched, some almost profusely towards their bases, others more commonly as in Plate I., Fig. 2, towards the apex.



Cooke (1892) founded the genus *Neotiella*, which he described as possessing minute, sessile, patellate to cup-shaped fruit bodies covered with slender white hairs, disc richly coloured to white, asci cylindrical, 8-spored, ellipsoid to oblong, hyaline. The species recognised by Saccardo as belonging to the genus, either possess smooth or roughened spores. The majority are terricole in habit, frequently found nestling at the base of moss plants, others are lignicole, usually growing on decaying wood. Corner (1929) states that "few discomycetes are known to be parasitic on bryophytes, though many live amongst such plants." He describes an operculate discomycete with the vegetative characters of a mildew and fruit bodies which resemble perithecia. Corner places his fungus in the genus *Neotiella* as *N. Crozalsiana* Grelet, which he records as an ectoparasite in England, on *Plagioclila asplenioides* (L.) Dum., discovered in France in 1924.

*Neotiella Crozalsiana* has smooth spores with thickened ends, and possesses appressoria and special haustorial branches which penetrate the cells of the liverwort.

The only example of a reticulate spored form is met with in *Neotiella Rozzi* Boud., which differs widely from *Neotiella Catharinaea* however, in regard to size of fruit body, colour of hymenium, spore measurements and habit.

The unusual situation of the apothecia in the axils of the moss leaves, and the reticulate sculpturing of the spore wall are the outstanding characters of the new species, and on account of the habit of the fungus on the moss plant *Catharinaea* it is named *Neotiella Catharinaea* spec. nov.

## HUMAREAE.

### LAMPROSPORA POLYTRICHINA (Rehm) Seaver.

Apothecia single or gregarious, sessile, at first sub-globose, becoming scutellate or shallow cup-shaped, reaching a diameter of 1 cm., margin wavy; hymenium carnelian red to vinaceous-rufous; asci cylindrical, not coloured blue with iodine; spores 1-seriate, smooth, hyaline, from 13–16 $\mu$  in diameter, filled with numerous oil drops; paraphyses slender, usually curved at the apices and filled with orange granules.

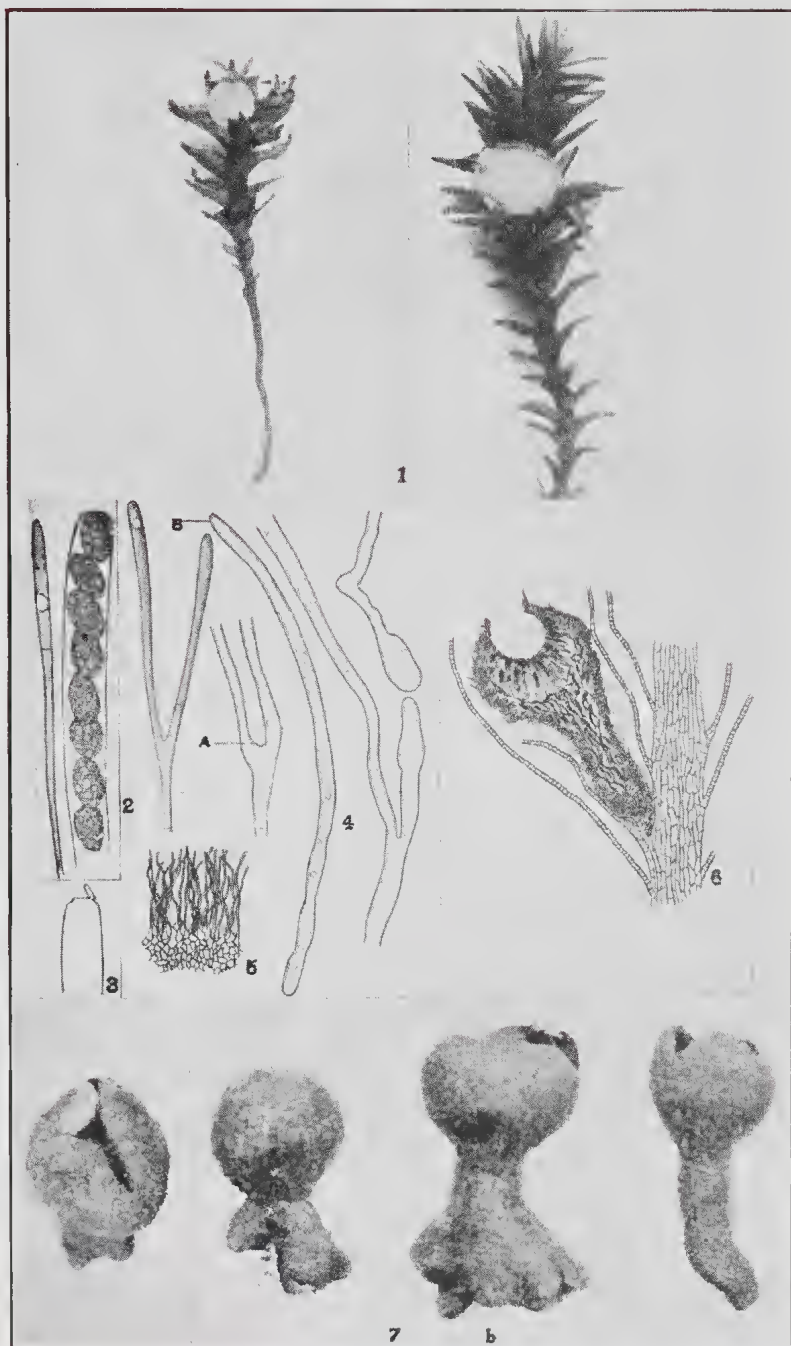
Recorded by Cooke (1892) for Australia (Victoria), and New Zealand as *Humaria miltina* Berk. and by Rodway (1924) for Tasmania as *Barlaca miltina* Berk. The specimens from which the above description was made were collected at Heathmont and Sandringham on burnt ground amongst mosses.

Type Locality.—Europe.

Distribution.—America, Europe, Australia (Victoria and Tasmania), and New Zealand.







*Neotiella Catharinaea*.

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# Explanation of Plate II.

- Fig. 1.—Plants of *Neotiella Catharinaca* sp. nov. on *Catharinaca* Mülleri Hamp. et C. Müll.  $\times 2$ .
- Fig. 2.—Portion of ascus of *N. Catharinaca* showing spores, and paraphyses.  $\times 174$ .
- Fig. 3.—Operculate ascus of *N. Catharinaca*.  $\times 174$ .
- Fig. 4.—Septated hairs of *N. Catharinaca*.  $\times 174$ . A. Branched hair. B. Blunt apex.
- Fig. 5.—Exciple with fringe of hairs—*N. Catharinaca*. (Diagrammatic.)
- Fig. 6.—L. S. through an apothecium of *N. Catharinaca* in the axil of a leaf of the moss. (Diagrammatic.)
- Fig. 7.—Plants of *Sarcosphaera funerata* (Cooke) Seaver. Nat. size. (a) Viewed from above. (b) Viewed from the side.

[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. I., 1936.]

ART. VII.—*An Upper Oligocene Bryozoan Faunule.*

By LEO. W. STACH, B.Sc.

[Read 9th July, 1936; issued separately, 23rd November, 1936.]

**Introduction.**

The forms listed below were obtained from approximately 40 cc. of matrix in the National Museum collections taken from 66-67 feet in the Torquay bore (Chapman, 1922). This faunule, though scanty, is interesting, because of the occurrence of well-preserved specimens of *Otionella cupola spiralis* (Chapman, 1913), and the extension of the range of *Cellaria depressa* Maplestone, 1900, to the Upper Oligocene. Notes on three of the species of the faunule are given below. The great predominance of cellariform elements in the sample suggests that deposition took place in shallow water (10-15 fathoms) subject to strong wave action (Stach, 1936).

My thanks are due to Mr. H. Marriott, of the Anatomy Department, University of Melbourne, for the photographs illustrating this paper.

**List of Species.**

*Otionella cupola spiralis* (Chapman, 1913). O-M.

*Cellaria australis* Macgillivray, 1880. O-R.

*Cellaria contigua* Macgillivray, 1895. O-P.

*Cellaria depressa* Maplestone, 1900. O-M.

*Cellaria rigida perampla* Waters, 1882. O-P.

*Cellaria rigida venusta* Macgillivray, 1895. O-M.

*Cellaria robusta* Maplestone, 1902. O-M.

*Cucullipora tetrasticha* Macgillivray, 1895. O-M.

O = Oligocene, M = Miocene, P = Pliocene, R = Recent.

**Notes on the Species.**

Family CELLARIIDAE Hincks, 1880.

Genus **Cellaria** Ellis and Solander, 1786.

CELLARIA DEPRESSA Maplestone, 1900.

*Cellaria depressa* Maplestone, 1900, p. 167, pl. xviii., fig. 15; *idem*, 1904, *b*, p. 193.

Distribution.—Lower Miocene. The following localities are additional to those listed by Maplestone (1904, *b*):—Batesford tunnel marl; Balcombe Bay; Mitchell River at Bairnsdale; Clifton Bank (Muddy Creek, Hamilton).

Upper Oligocene: 66-67 feet in the Torquay bore; "Glyeimeris bed" (Torquay).

Family MEMBRANIPORIDAE Busk, 1854.

Genus **Otionella** Canu and Bassler, 1917.

OTIONELLA CUPOLA (Tenison Woods, 1879).

(Pl. III., Fig. 3; text figs. 2, 3-5.)

*Lunulites exigua* T. Woods, 1879, p. 8, pl. ii., figs. 7a-c.

*Lunulites cupola* *idem*, 1879, p. 8, pl. i., figs. 5a-c.

*Lunulites petaloides* Waters (*non* d'Orbigny, 1852), 1883, p. 442.

*Selenaria cupola* (T. Woods), Macgillivray, 1895, p. 49, pl. vii., fig. 14. Maplestone, 1904, *a*, p. 210; *idem*, 1904, *b*, p. 198. Chapman, 1916, p. 387; *idem*, 1922, pp. 317-319; *id.*, 1928, p. 148.

Observations.—The type material of this species (preserved in the Tate Museum, Adelaide University) consists of a series of five zoaria of "*Lunulites exigua*" from Mount Gambier and eight zoaria of "*Lunulites cupola*" from Muddy Creek, Hamilton (lower beds). The zoaria of each series have been treated as syntypes (labelled alphabetically) since it cannot be decided which specimens were figured.

The two series of syntypes were compared and the opinion of Maplestone (1904, *a*) as to their conspecificity is confirmed. The zoaria from Mount Gambier ("*Lunulites exigua*") are abraded and partly obscured by secondary deposition of calcite, while the dimensions are proportionately smaller than the average for the species, the last-named feature being due probably to the contemporary local environment. The zooecial and vibraecular detail which can be made out agrees with that of the Muddy Creek specimens ("*Lunulites cupola*"). The characteristic development of the zoarium up to the stage A 4, B 4 (Figs. 5, 6) can be seen in both series of syntypes.

Maplestone, the first reviser of these forms, chose the name "*cupola*" for the revised species, and this name must stand although "*exigua*" has page precedence (Art. 28, Internat. Rules Zool. Nomen.).

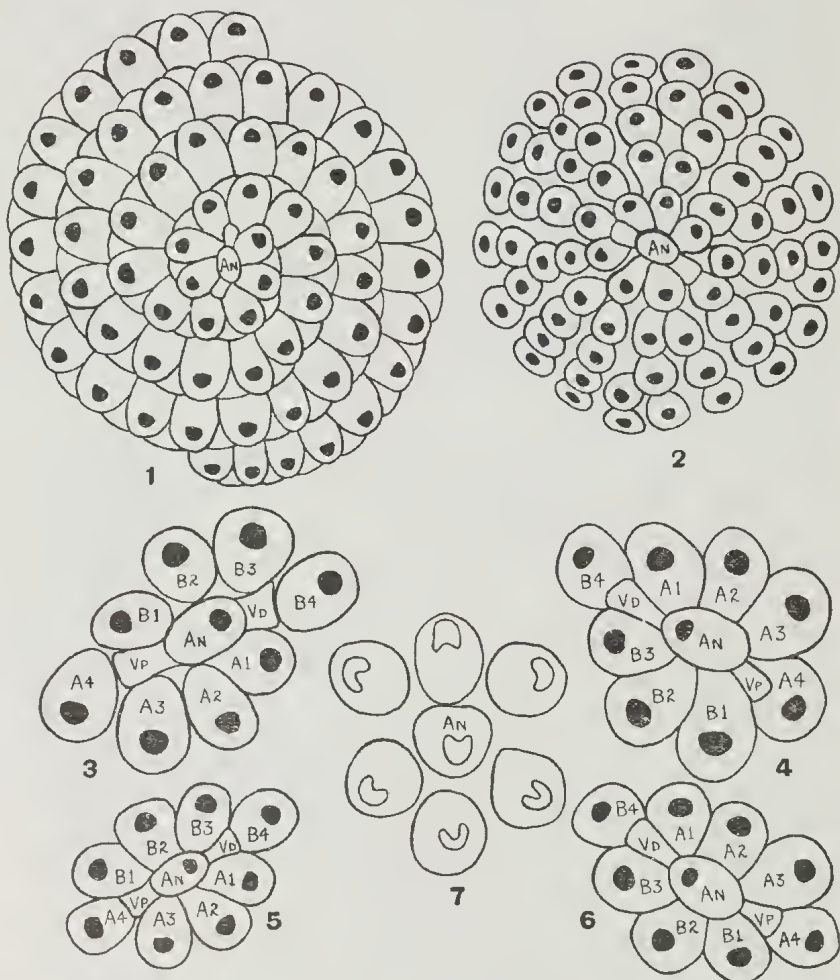
Maplestone (1904, *a*) has placed the New Zealand Tertiary form, *Selenaria squamosa* T. Woods, 1880, with this species, but an examination of the types of *S. squamosa* (by courtesy of the New Zealand Geological Survey) shows that the vibraecula of this form have the large eribriform frontal area typical of *Selenaria*.

OTIONELLA CUPOLA SPIRALIS (Chapman, 1913).

(Pl. III., Figs. 1, 2; text figs. 1, 3.)

*Selenaria marginata* var. *spiralis* Chapman, 1913, p. 184, pl. xviii., fig. 33; *idem*, 1916, pp. 377, 387, pl. lxx., fig. 33.

Affinities.—The ancestrular region of the poorly preserved holotype (Nat. Mus. Coll. No. 12456) has been abraded off,



FIGS. 1-7.—Schematic outline camera lucida drawings of zoaria and ancestrular regions of *Otionella cupola* and *Selenaria concinna*.

Fig. 1. Zoarium of *Otionella cupola spiralis* (Chapman) from Torquay Bore at 66-67 feet, illustrating clockwise double spiral mode of development of the whole zoarium. X 20. Fig. 2. Zoarium of *O. cupola cupola* (T. Woods) from "Glycimeris bed" at Torquay, illustrating distal budding of zooecia following spiral development of ancestrular region. X 20. Fig. 3. Ancestrular region of *O. cupola spiralis* from Torquay Bore at 66-67 feet. X 40. Fig. 4. Ancestrular region of *O. cupola cupola* from "Glycimeris bed" at Torquay. X 40. Fig. 5. Ancestrular region of Syntype C of "*Lunulites exigua*" from Mount Gambier. X 40. Fig. 6. Ancestrular region of Syntype G of "*Lunulites cupola*" from Muddy Creek, Hamilton (lower beds). X 40. Fig. 7. Ancestrular region of *Selenaria concinna* T. Woods from Clifton Bank, Muddy Creek (Hamilton). X 40. An, ancestrula; A1-A4, earliest zooecia of the distal spiral; B1-B4, earliest zooecia of the proximal spiral; Vd, distal vibraculum; Vp, proximal vibraculum.



but the younger zooecia permit a definite correlation with *Otionella cupola* in the form and dimensions of the aperture, the dimensions of corresponding zooecia in zoaria of *O. cupola spiralis* from the present locality and particularly in the form of the vibraculum, that of *Selenaria marginata* being much expanded proximally, whereas in *O. cupola* the vibraculum is narrow in the proximal region. The ancestrular region of *S. marginata* differs markedly from that of *O. cupola*, but corresponds closely with that of *Selenaria concinna* T. Woods, 1879 (cf. figs. 3 and 7).

Zooecia and vibracula.—A comparison of the characters of the zooecia and vibracula of *O. cupola cupola* and *O. cupola spiralis* reveals no character by which they could be separated. The dimensions of the zooecia are variable on the same zoarium, but a measurement taken between the distal edges of zooecia A 4—B 4 is significant (Fig. 3). In *O. cupola spiralis* six zoaria gave a measurement of 0.95 mm. and two a measurement of 1.0 mm. For several zoaria from varying horizons and positions in the "*Glycimeris* bed" at Torquay *O. cupola cupola* gave a range from 0.85–1.15 mm., the mean of which agrees closely with that of the former variety. The range in the measurements of *O. cupola cupola* is probably due to varying environmental conditions since the zoaria came from several sources whereas, in the case of *O. cupola spiralis*, only about 40 cc. of matrix from the one source yielded the specimens.

The only distinction between *O. cupola spiralis* and *O. cupola cupola* is the mode of zoarial development.

Zoarial development.—The substratum for the zoarium in all observed cases was a glauconite grain. The ancestrula, which is of the same character as the zooecia, buds off two vibracula, one at the proximal end and the other at the distal end, the former probably being developed to maintain the balance of the young zoarium. In the angle on the right side between the distal vibraculum and the distal half of the ancestrula and in the angle on the left side between the proximal vibraculum and the proximal half of the ancestrula, the first two zooecia (A 1, B 1) are developed. From the right hand side of each of these is budded laterally a zooecium which abuts on the remainder of the lateral wall of the ancestrula on each side (A 2, B 2). The third pair of zooecia (A 3, B 3) are budded laterally from the preceding pair, their proximal ends abutting on the left lateral walls of the vibracula. The fourth pair of zooecia (A 4, B 4) arise in similar fashion, their proximal ends abutting on the distal wall of each vibraculum. The succeeding zooecia are budded laterally from the right side of each preceding zooecium and thus the zoarium is formed of two clockwise spiral series of zooecia. The latest zooecia of each spiral composing the zoarium are always seen to be on opposite sides of the zoarium and counts

of the zooecia in each spiral for several zoaria gave the following results: 31, 30; 30, 30; 28, 26; 26, 25; 19, 18; 18, 17; 15, 14. These figures illustrate that the budding rate is the same in each spiral, probably being controlled by the need of the zoarium to maintain its balance.

In *O. cupola cupola* the development up to the stage of A 4, B 4 (Fig. 4) is essentially the same as described above except that various minor irregularities in the positions of the earlier zooecia occur and in a few cases additional zooecia are interpolated in the original series. When the ancestrula and its pertaining vibracula have become completely surrounded by zooecia, budding takes place from the distal ends of the zooecia (Fig. 2), the resulting zoarium being circular in outline. This later development of higher symmetry in the zoarial form appears to be correlated with the maintenance of balance by the zoarium.

The only other case in which a double spiral development of the zoarium is known is that of the recent *Heliodoma implicata* Calvet, 1906, from Madeira, but there is no close genetic connexion between these two forms since there is no relation in the early development of the zoarium and the great development of the elongate opesium in *Heliodoma* contrasts strongly with the small subcircular opesium of *Otionella*. The sporadic occurrence of this type of zoarial form and, in the case of *O. cupola spiralis*, its correlation with a form having a lunulitiform zoarium suggest that the significance of this type of development is small. It is suggested that *Heliodoma* belongs to the widely-distributed, better-known genus *Cupuladria* Canu and Bassler, 1920, for the following reasons.

Apart from the difference in zoarial form, Canu and Bassler (1920, p. 24) state that these genera differ only in the place of the vibracula. Actually the difference in situation is only apparent and of little morphological importance. In *Cupuladria* it is obvious that each vibraculum develops as a distal bud from each zooecium. The mode of development of the colony of *C. canariensis* (Busk, 1859) (the genotype) is such that each vibraculum is finally situated proximal to the longitudinal plane of symmetry of the distal zooecium, while the long axis of the vibracular aperture is acutely inclined to that of both proximal and distal zooecia. An examination of Calvet's figure of *Heliodoma implicata* indicates the same mode of development of the vibraculum, but the situation of the vibraculum appears to be between the distal ends of adjacent zooecia, this being due to the mode of development of the colony, for the figure shows that the latest zooecia of both spirals each have a vibraculum budded off from their distal ends (although not quite in the plane of the longitudinal axis of the zooecium). Thus the apparent difference in situation of the vibracula depends merely on the zoarial form of the colony, the morphological relations

of zooecium and vibraculum in both species being identical. If this suggestion is confirmed, *Cupuladria* will pass into the synonymy of *Heliodoma*.

Distribution.—In the Tertiary deposits of southern Victoria, *O. cupola spiralis* has been found only in the Upper Oligocene at the present locality, whereas in the Murray Gulf it persisted until the Miocene (Chapman, 1913, p. 185). *O. cupola cupola* is very widely distributed in Victorian Lower Miocene deposits, additional localities to those listed by Maplestone (1904, b) being Batesford tunnel marl and Forsyth's (below remanié nodule bed), Grange Burn Creek (Hamilton). Chapman (1922) has recorded "*Selenaria cupola*" down to 59 feet in the Torquay bore and it is possible that some of these may be *O. cupola spiralis*. Further records by Chapman (1916, 1928) indicate the occurrence of *O. cupola cupola* in the late Miocene and early Pliocene of the Mallee and Sorrento bores.

Family SCHIZOPORELLIDAE Bassler, 1935.

Escharellidae Levinsen, 1909, p. 314.

Schizoporellidae Bassler, 1935, p. 33.

Sub-family HIPPOPORININAE Bassler, 1935.

Hippopora Canu and Bassler, 1917, p. 42; *idem*, 1920, p. 398; *id.*, 1927, p. 19; *id.*, 1929, p. 33. Darteville, 1933, p. 78.

Hippoporininae Bassler, 1935, p. 33.

Genus **Cucullipora** Macgillivray, 1895.

*Cucullipora* Macgillivray, 1895, p. 95. Canu and Bassler, 1929, pp. 34, 41. Bassler, 1935, p. 85.

*Hippozeugosella* (*pars*) Canu and Bassler, 1920, p. 398.

Observations.—The name changes of higher order than the genus are due to nonconformity with Article 4 of the International Rules of Zoological Nomenclature. The systematic position of this genus has been uncertain since its inception. Macgillivray's original placing of it in Smittinidae was altered to sub-family "Hippopora" by Canu and Bassler (1920, p. 398) while the genus was combined with *Bactridium* Reuss, 1848, to form a new genus *Hippozeugosella* Canu and Bassler, 1917. Darteville (1933, p. 78), apparently in communication with Canu, states that Canu and Bassler now regard the three genera mentioned above as distinct. In 1935 Bassler transferred *Cucullipora* to Hippopodinidae Levinsen, 1909, following the suggestion of Canu and Bassler (1929, p. 41) that it is possibly related to *Watersipora* Neviani, 1895 (the character of the aperture, however, contradicts this), while *Hippozeugosella* was placed in the synonymy of *Bactridium*, both the latter having the same genotype.

The study of a large series of *Cucullipora tetrasticha* now shows that it is most closely related to *Hippoporina* Neviani, 1895,

type of the sub-family Hippoporininae, thus agreeing with the first placing of Canu and Bassler. The evidence for this is provided by the typically Hippoporine form of the aperture and the large cardelles, the frontal being an olocyst. Although about fifty examples have been examined, none has been found bearing ovicells. From *Hippoporina* it differs in the form of the zoarium, hood-like peristome and the arrangement of the avicularia.

CUCULLIPORA TETRASTICHA Macgillivray, 1895.

(Pl. III., Fig. 4).

*Cucullipora tetrasticha* Macgillivray, 1895, p. 96, pl. xiii., fig. 13. Maplestone, 1904, *b*, p. 211. Dartevelle, 1933, p. 78. Bassler, 1935, p. 85.

*Hippozugosella tetrasticha* (Macgillivray), Canu and Bassler, 1920, p. 398.

Dimensions.—Width of branch, 1.15 mm.; aperture, height 0.12, width 0.09; zoecium, length 0.56.

Distribution.—Lower Miocene: The following localities are additional to those listed by Maplestone (1904, *b*):—Batesford tunnel marl, Curlew marl.

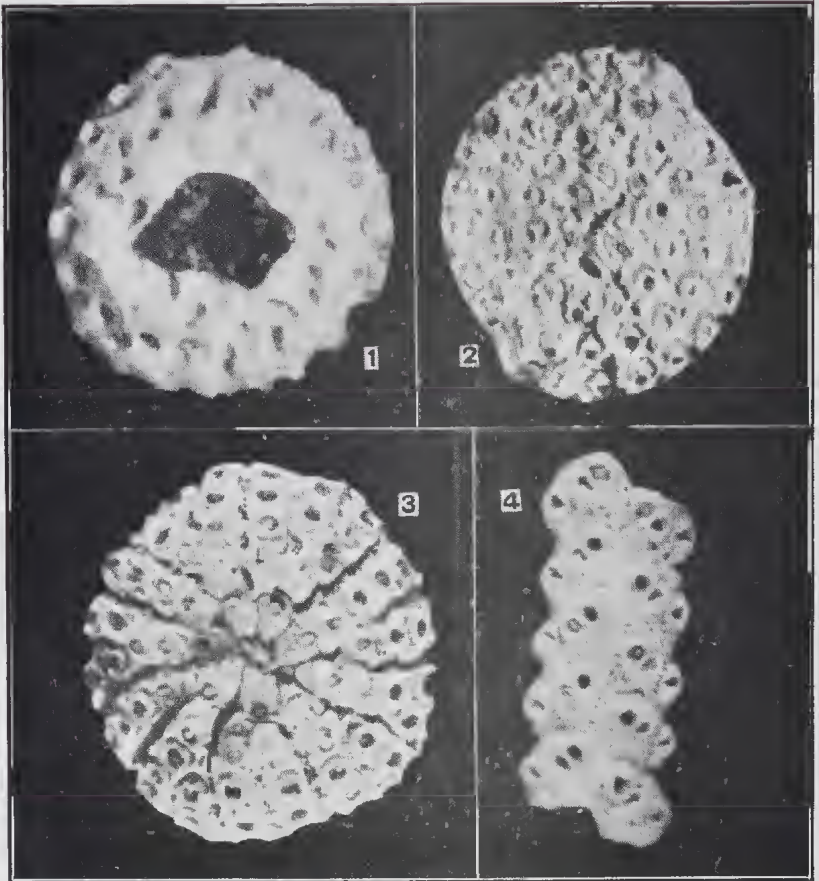
Upper Oligocene: Torquay bore at 66-67 feet.

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Upper Oligocene Bryozoa.



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### Explanation of Plate III.

(Magnification  $\times 17.5$ .)

- Fig. 1.—*Otionella cupola spiralis* (Chapman). Mallee Bore No. 9 at 315-325 feet. Holotype, in National Museum, Melbourne (No. 12456), showing glauconitic grain as substratum for the zoarium, the first few whorls of the spirals having been abraded off.
- Fig. 2.—*O. cupola spiralis* (Chapman). Torquay Bore at 66-67 feet. Plesiotype in National Museum, Melbourne (No. 14052), showing complete zoarium except for the slightly damaged ancestrular region.
- Fig. 3.—*O. cupola* (T. Woods). "Glycimeris bed" at Torquay. Plesiotype in National Museum, Melbourne (No. 14053).
- Fig. 4.—*Cucullipora tetrasticha* Macgillivray. Clifton Bank, Muddy Creek (Hamilton). Plesiotype in National Museum, Melbourne (No. 14054).

[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. I., 1936.]

ART. VIII.—*A Staining and Maceration Method of Tracing the Path of the Vascular Bundles in Herbaceous Plants, and its Application in Observations on the Distribution of Bacterium solanacearum in Relation to Epinastic Curvatures in Petioles of Tomato and Potato Plants.*

By B. J. GRIEVE.

[Read 9th July, 1936; issued separately, 23rd November, 1936.]

### Introduction.

In certain plants infected by *Bacterium solanacearum* it has been shown (3, 5, 6) that petiole-epinasty and adventitious root production occur. In experiments designed to show the relation of the bacteria to the epinasty and root formation, the following method was developed.

Healthy tomato plants were first used. The stems were severed at the base, and the plants placed in 1 per cent. solutions of eosin or basic fuchsin from one to two hours, until the dye was definitely visible in the veins of the topmost leaves. After removal from the dye solution, the petioles were cut off at a distance of about one-half inch from the stem. The epidermis was then slit along the stems and petiole bases with a sharp scalpel, and the plants immersed in dilute nitric acid (15 per cent.) which had been raised to boiling point. This strength of acid had been found suitable by Wilson (7) in his experiments to obtain epidermal tissues from leaves. The period of immersion in the acid was a few seconds in the case of tomato stems, but varied from one to five minutes for well developed potato stems. The plant was generally found to be in a suitable state of limpness for dissection by the time numerous bubbles were seen arising from the cut ends of the stem immersed in the gently boiling acid. On removal from the acid the plants were washed in running water for ten minutes, and then allowed to stand in water overnight. The epidermal and cortical tissues could then be easily dissected away with fine pointed forceps. The vascular tissue and the eosin and basic fuchsin dyes were unaffected by the acid treatment so that the path of the bundles could be easily traced. Other dyes, particularly light green as recommended by Harvey (4) were tried, but this dye and certain of the others showed a tendency after the acid treatment to lose colour or to become diffused throughout the parenchyma tissue. The red dyes also afforded a greater visual and photographic colour contrast with the bacterially filled bundles.

The method is specially useful in anatomical work on herbaceous plants and obviates in large measure the laborious serial sectioning method of recording the path and forkings of the bundles. Thus for potato, it enables one to trace the course of the bundles and to confirm Artschwager's (1) reconstruction of them made from a great number of transverse sections. The method was next applied to tomato and potato plants in various stages of the disease caused by the vascular parasite *Bacterium solanacearum*. The dye was taken up either through the base of the cut stem or through cut roots. Vessels clogged with bacteria failed to allow the passage of the stain, and on dissection, the infected bundles showed a yellowish appearance in contrast to the red of the non-bacterially invaded vessels. The method incidentally provides an illustration of the fact that the water of the transpiration stream travels essentially in the lumen of the vessels. Where the invasion and clogging of the vessels was general, the stain did not penetrate upwards at all.

In order to outline more clearly the longitudinal extent of the bacterially-invaded parts of the vessels, advantage was taken of the fact that on cutting a petiole or leaf near the top of the plant under a water solution of the dye, some of this is sucked back into the vascular system of the plant by the negative pressure in the water system. Using the method of Caldwell (2), and a modification of it, whereby plasticene cups to hold the dye were built around the petiole, it was possible to delimit fairly accurately the infected vessels from above and then from below, by the uptake from the roots. As a check on the technique, transverse sections of the petioles were cut about one-half inch out from the stem before its treatment with acid. The presence or absence of bacteria could be determined in this way, and then checked by the maceration method. The staining method facilitated the determination of the presence or absence of bacteria in the vessels in the examination of transverse sections.

In connexion with the adventitious root formation which occurs in tomato as a reaction to infection by *B. solanacearum*, it was of interest to trace the line of development of the roots along the stem, and to determine where they developed in relation to the bacteria. The stain and maceration method proved quite useful here provided that more care was exercised in dissecting away the tissue around the developing roots.

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### Explanation of Plate IV.

- FIG. 1.—Diagrammatic representation of the course of the vascular bundles in *Solanum tuberosum* as obtained by the staining and maceration method. The path taken by the invading bacteria is indicated by the dots.
- FIG. 2.—Potato stem dissected to show the path of the vascular bundles. All bundles are full of bacteria and appear yellow in the preparation.
- FIG. 3.—Potato stem dissected. The dark appearing bundles are free of bacteria and have taken up the eosin, while the light coloured bundles are full of bacteria.

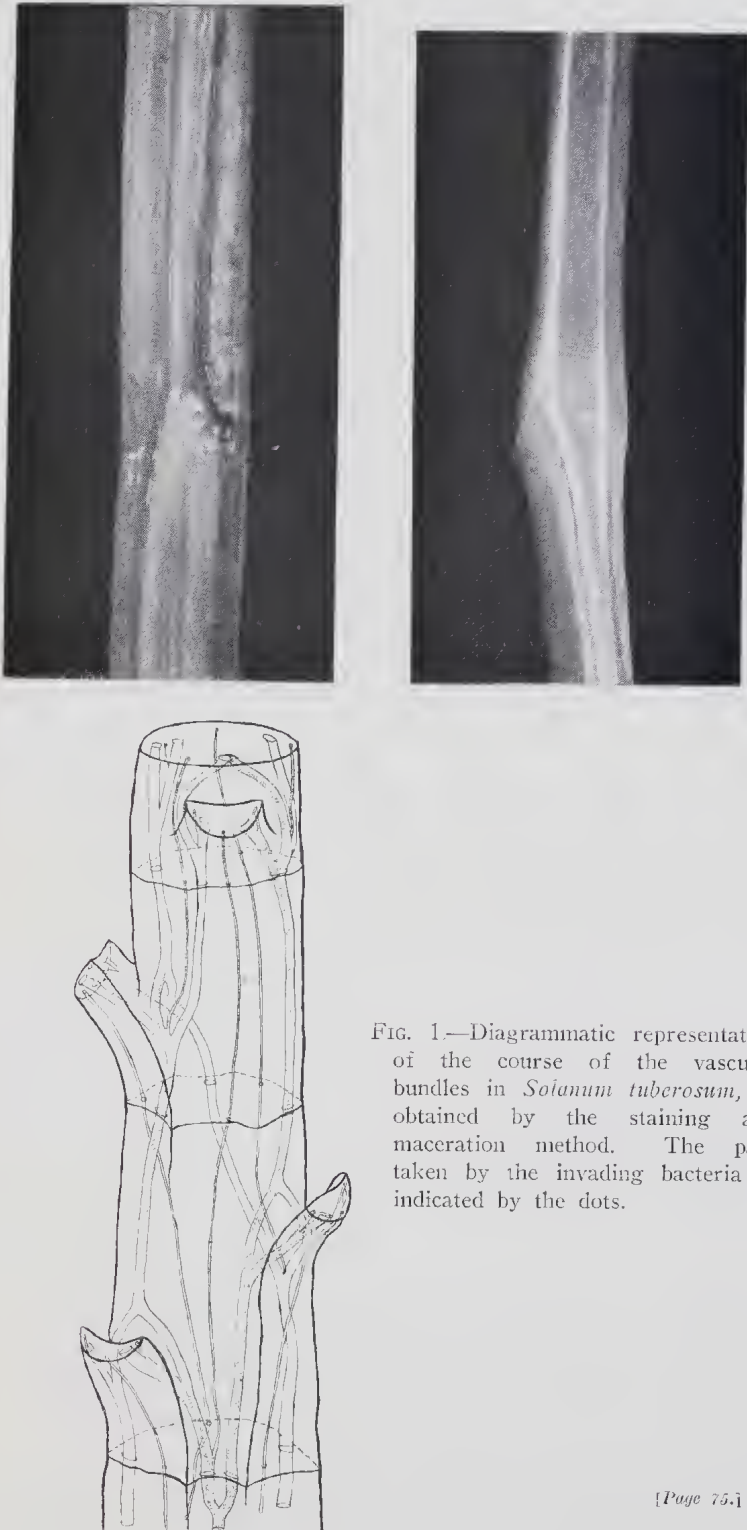


FIG. 1.—Diagrammatic representation of the course of the vascular bundles in *Solanum tuberosum*, as obtained by the staining and maceration method. The path taken by the invading bacteria is indicated by the dots.





[PROC. ROY. SOC. VICTORIA, 49 (N.S.), Pt. I., 1936.]

ART IX.—*Soil and Pasture Studies in the Mount Gellibrand Area, Western District of Victoria.*

By G. W. LEEPER, M.Sc., ANN NICHOLLS, M.Sc., AND  
S. M. WADHAM, M.A., Agr. Dip.

[Read 9th July, 1936; issued separately, 23rd November, 1936.]

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### I. Introduction.

The large area of land derived from basaltic material in the south-western part of Victoria is interesting from several points of view. Part of it produces high-grade wool; in other sections there are extensive dairying settlements; and near the volcanic cones, which are scattered about the district, there are fertile soils which are largely used for producing crops such as onions and potatoes. Even casual observations show that the number of soil types is quite considerable, although the basalt itself is petrologically uniform over wide areas. A detailed study of a single area in this district has been undertaken in order to obtain useful information concerning a group of soils about which little has as yet been published, and also to explain some of the reasons for the differences between these types. Since this volcanic country includes various kinds of pasture, and numerous attempts at improvement of pastures have been made with varying success, the relation between soil types and pasture has also been studied.

It was decided to choose for this survey some point that would be typical of the volcanic country, and in which the geology would not be complicated by non-basaltic material. Mr. R. A. Ramsay of "Mooleric" and Mr. Urquhart Ramsay of "Turkeith" were kind enough to agree to co-operate in this work. These two stations comprise about 12,000 acres, and are fairly close to the Prince's Highway at a point about half way between Winchelsea and Colac. Mount Gellibrand near the centre of this region provided one volcanic cone in the area surveyed.

Surveyed maps of the stations, on a scale of 1 to 6,336 were made available through the courtesy of the owners, and these were used for the first stages of the survey. However, after the main soil types had been recognized, it was clear that it would be very laborious to try to map the area on the ground, owing to the extent to which the various types are interwoven. The Royal Australian Air Force were therefore approached, and asked if they could make the area the subject of a photographic survey. They very courteously agreed to help, and the photographs were taken on 30th September, 1932, when the water from the winter rains was still lying on the least drained swamps, and the spring growth had begun on the drier land. Three photographic mosaics, on a scale of 1 to 6,840 were prepared, and these were used in the field for the next visit. These aerial photographs were invaluable, and, as will be shown in more detail below, it was possible after a few days' experience to identify each type

of soil and map it directly from the photograph. These sketches were then checked by visiting each paddock, and identifying in the field the soils deduced from the photograph; the final map is reproduced in this paper.

## II. Topography.

The area studied forms part of the general plain of the Western District. The central feature is Mount Gellibrand (872 feet), a volcanic cone with a flat top about half a mile in diameter, its sides having a slope of approximately 20 deg. The regularity of the cone is broken by occasional outcrops of basaltic rock, and also, on the south-eastern side, by a small subsidiary cone—"Little Mount". On the western side, a flow of basalt extends from the cone for half a mile over the plain. The steep sides of the cone pass by a sudden transition to gentler gradients which extend outwards for about a mile to the south-east, and half a mile to the north, west, and south.

On the eastern boundary of the area lies Mount Pleasant (500 feet), a much smaller volcanic cone of gentle slope, rising only about 100 feet above the general level of the plain. A flow of basalt from this cone has covered the north-eastern corner of Mooleric station, so that this section lies about 50 feet above the rest of the plain.

Elsewhere, the plain averages about 400 feet above sea level, and falls away very gradually from the mount in all directions. The plain is marked by numerous "stony rises", which are a striking feature of the country (see Plate VI., Fig. 3). These rises are rocky mounds ranging in height up to about 20 feet, and varying in steepness, shape and extent. Their distribution is for the most part irregular, but some give the impression of being connected into chains. The most conspicuous of these chains occurs in the south-eastern part of the area, where a high wall with occasional breaches extends for about two miles. The rises show great variation from this extreme case down to low outcrops of basalt which, though scarcely worthy of the name of rises, have a considerable effect on the soil. Those rises which have a large area are often broad and flat and comparatively free from rocks; swamps are often developed on such rises. Small swamps are also common at the foot of the steeper rises at the point where the gradient changes abruptly.

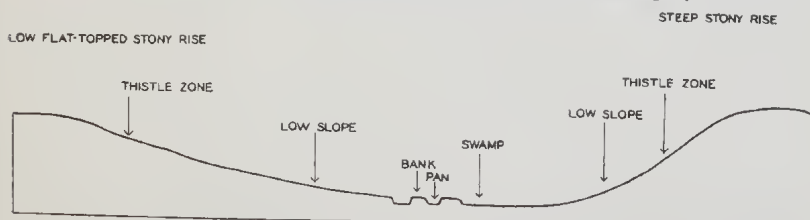


Fig. 1. Section from Stony Rise through Swamp to Stony Rise.

Surrounding each stony rise and varying with it in size and shape is an area of gently sloping ground free from basalt boulders. This changes gradually to flatter ground with typical swamp formations, which will be described later. These transitions are illustrated in Fig. 1. Apart from the mount, the entire country studied may be regarded as a repetition of the sequence stony rise—rock-free slope—swamp—slope—stony rise.

The central position of the Mount, and the fact that there is a gentle slope away from it in all directions, together offer the key to the drainage of the area. The south-west section drains away to Lake Thurrumbong, a somewhat saline, impermanent sheet of water. The south-east section, in which the gradient is rather greater, drains to the Barwon River. The north-east section drains directly to Lake Murdeduke, which is highly saline. The north-west section drains to Lake Calvert, which, in very wet seasons, overflows into Lake Murdeduke. There are no natural water-courses in the area, drainage consisting merely of the movement of water from one swamp to another during the period of heaviest rain. This is probably due to the very gentle fall in general level of the plains, combined with the interruption of the main drainage flow by the irregularly placed stony rises.

### III. Geology.

#### A. HISTORY OF THE AREA.

In late Tertiary times this part of Western Victoria was apparently low-lying country which was affected by the extrusion of basaltic lava. The Geological Survey records this lava as "Newer Basalt", and from the evidence in different parts of Western Victoria, this period of volcanic activity is said to have been in the late Tertiary and lasted until the end of the Pleistocene period. There is, therefore, the possibility of a difference in age of flows belonging to the "Newer Basalt" of the order of a million years, and such a difference must be important in the comparison of soils from different Newer Basaltic areas.

In the Mount Gellibrand area, the evidence of numerous bores indicates a basalt layer varying in thickness from 20 to 200 feet. Friable bands, which are almost invariably encountered during boring, suggest that there have been several flows of basalt, separated by layers of tuffaceous material, or by soil formed on the surface of one flow before the extrusion of the next. The gradual fall in general level away from the mount suggests that it was a centre of effusive activity, although the Newer Basalts are sometimes thought to be of the fissure-eruption type.

The small flow of basalt from Mount Pleasant across the north-eastern part of Mooleric station probably occurred after the extrusion of the main basalt sheets, since it appears to overlie them. The volcanic activity then became more violent, and the central cone of Mount Gellibrand was formed. This cone

consists of bedded tuff and scoriaceous material, and its centre is filled by a plug of compact basalt. There are evidences of minor explosive vents, while numerous outcrops of very dense basalt are the result of dykes formed in the crater wall. The basalt flow mentioned as occurring on the west side of the cone ("Rocky Mount") probably represents a flow from one of these dykes.

As already noted, the lower slopes of the mount extend further towards the south-east than in any other direction. This is presumably due to the direction and intensity of the winds prevailing during the period of violent eruption. At the present time; the prevailing winds during winter and spring come from the north and north-west. Since the main physiographic features of the continent had already taken their present shape at the time of the eruption, one may assume that the prevailing winds of those days came from the same quarter as at present.

Apart from the mount, there is no evidence of bedded tuff over the area, but a large amount of fine material must have accompanied the coarser fragments and accumulated to a considerable depth over the basalt sheets of the plain. Evidence for this is found in the presence of a large proportion of quartz grains in most of the soils of the plains. Much of this quartz belongs to the coarse sand fraction of the soil, and is therefore too large to have been brought in from other districts by the wind.

The stony rises are characterized by columnar jointing on a large scale, with the joints at right angles to the exterior slope of the rise. This feature proves that the original cooling surface of the lava had the same topography as the present surface, and that the rises are original features of the basalt and not merely residual mounds left during the process of erosion. The surface of the blocks is bare, but soil fills the cracks. The proportion of soil to rock decreases as the rises become steeper. The origin of these stony rises is somewhat doubtful, and from the standpoint of soil formation is important only in connection with their age in relation to the ash. As will be seen from the description of the soil minerals, the deposits of ash from Mount Gellibrand appear to have covered the rises, which must therefore be older than the explosive phase. The absence of bedded tuff or ash over the plains makes it probable that the explosive material was deposited over the cooled surface of the basalt, and so suffered no hardening and was not preserved as consolidated rock.

The ash has now been almost completely removed from the summits of the rises, and it is probable that most of it was washed away either by volcanic rains accompanying the eruption, or by later rain acting on the fine unconsolidated material. Any soil forming on the surface of the rises is at present removed in a similar manner.



## B. PETROLOGY.

*Volcanic Scoria and Tuff.*

The materials formed during the explosive phase of eruption show great variation. On the mount, reddish-brown vesicular lava occurs, but is not as common as bedded grey tuff with well-marked bands of fine and coarse fragments. In one restricted locality on the north-east slopes of the mount, numerous rounded pebbles up to 2 inches long occur in the tuff. Most of these are of reef quartz, but a few consist of sedimentary rock with fine quartz veins. These pebbles appear to be water-worn, and probably represent pre-basaltic river gravels thrown out by the volcano during a minor eruption.

These fragmental rocks are incoherent, and accordingly difficult to section, but the sections obtained serve to show that they are typical basalt tuffs. Much of the rock consists of brown, highly vesicular glass in which well-formed olivine phenocrysts up to 2 mm. in diameter are common, sometimes with a narrow border of iddingsite. Lath-shaped crystals of plagioclase occur in all the sections, their size depending on the degree of crystallization of the lava fragments. Augite and iron oxide occur rarely, and only in the more crystalline material.

A varying amount of non-basaltic material, mainly quartz, is included in the tuff. The grains of quartz are usually rounded, and often contain lines of bubbles such as are common in reef quartz. They show no noticeable reaction rim, and probably represent pre-basaltic material such as marine Tertiary sands ejected by the volcano during its explosion. Other common detrital minerals such as zircon, tourmaline, and kyanite have also been observed in the tuff.

The amount of non-basaltic material in the tuff was determined by disintegrating the rock (by soaking with water and freezing) and counting the number of quartz grains in a definite sample of material of diameter between 0.2 and 0.02 mm. The grey banded tuff showed about 20 per cent. quartz, and the red scoria, which appeared to be the least contaminated of the fragmental rocks, showed 10 per cent. quartz. It seems likely that the finer ash which fell over the plains would be still richer in quartz grains, the larger and heavier fragments of basaltic lava being concentrated near the mount. The basaltic minerals in the fine ash would decompose very rapidly, leaving only the quartz.

*Basalt of the Plains.*

This is a grey, coarse-grained, vesicular olivine basalt. Microscopically it shows phenocrysts of olivine with a reaction rim of iddingsite varying in width, the whole crystal sometimes showing the iddingsite colouring. The ground mass consists of an ophitic intergrowth of augite and plagioclase feldspar, with grains of iron oxide, either magnetite or ilmenite. The augite has the



"titanium violet" tinge, suggesting that some at least of the iron oxide is ilmenite. The refractive index of the plagioclase is between 1.555 and 1.575, and very close to the latter, indicating a composition approximating to labradorite.

A varying amount of interstitial brown devitrified glass occurs, with a lattice-like growth of needles of iron oxide. This glass is particularly abundant around the numerous vesicles. These vesicles are often lined with hyalite.

Included fragments of reef quartz, up to 2 inches in diameter, have been observed in specimens from several localities, and these show a marked reaction rim.

Rosiwal measurements on five samples from different parts of the area gave the following average result: Plagioclase 37.0 per cent., Augite 22.5 per cent., Olivine 10.3 per cent., Iron oxide and glass 29.8 per cent.

#### *Basalt Dykes of the Mount.*

This basalt differs from the basalt of the plains in being extremely fine-grained and compact. Olivine phenocrysts (with the iddingsite alteration) and a few large augite crystals occur in a fine ground mass of the usual basaltic minerals. Included rounded quartz grains occur in these dykes, and show marked reaction rims. The plug which fills the centre of the cone is of the same nature.

### **IV. Description of Soil Types.**

The various types recognised in this survey are referred to here as Types 1, 2, etc. The individual samples have been numbered according to a decimal system by which the first digit or the first two digits correspond to a soil type—thus 401, 402, etc., all belong to type 1 (see below).

#### **A. SOILS OF THE PLAIN.**

The most striking features of the plain are the stony rises from which the land slopes down to swampy depressions. The soil types show well-marked changes as one passes from stony rise to swamp. Milne (1935, i., ii.) has suggested the word "catena" to cover a sequence of soils in cases where characteristic types have developed on hilltops, slopes, and basins; he quotes as an example a catena in Uganda including shallow greyish-black soil on the hilltops, deep red soil on the slopes, grey sandy soil on the fringe of the swamps, and intensely black acid clay on the swamps. The sequence here described from stony rise to swamp appears to be an excellent example of such a catena. While this variability is to be expected in a region of stony rises and irregular drainage, it is not characteristic of the whole of the volcanic plains of Western Victoria.

*(a) Soils with Surface Drainage.*

On the rises themselves, the rock is always close to the surface, and the soils fall into two classes, separated according to their depth.

Type 1.—STONY RISE BROWN LOAM. (Sample numbers beginning 40 . . .)

On many of the steeper rises, the soil is only three to six inches deep, and the rocks are in a fresh state and very close together. This soil is a friable brown to dark brown loam, often dusty; it is rich in organic matter, and of good fertility. From its shallowness and absence of horizons, and the presence in its sand fraction of large amounts of unweathered basaltic minerals, it appears that this brown loam is highly immature.

Type 2.—STONY RISE CLAY. (Sample numbers beginning 47 . . .)

Some rises have broad flat tops, and the outcropping rocks are then relatively far apart. The soil on these rises is a dark grey to dark brownish-grey clay loam or clay, about a foot deep. This type is used to include transitional forms between type 1 and types 4 and 5, but it is always more fertile than the latter types.

Type 3.—THISTLE-ZONE SOILS. (Sample numbers beginning 3 . . .)

A very conspicuous vegetational feature of the country is the band of thistles (*Carduus pycnocephalus*) surrounding each stony rise, and extending for twenty yards or more in every direction from the main outcrop. These thistles are associated with a soil type, of which the following profile is typical, although rock is often struck in this zone before the third foot has been bored:—

Horizon 1 (0 to 6 inches).—Dark grey or dark brownish grey clay loam or clay, somewhat friable, breaks up on drying into small cubes; sticky when wet. pH between 6 and 7.

Horizon 2 (6 to 25 inches).—Dark grey to black heavy clay, with a yellowish tinge appearing at about 20 inches. pH about 7 increasing with depth.

Horizon 3 (25 to 36 inches).—Greyish yellow calcareous clay, with maximum  $\text{CaCO}_3$  at about 36 inches, both as soft lime and as concretions up to an inch in diameter. This clay is plastic and only the more highly calcareous bands are at all friable. pH 8.0 to 8.5.

Horizon 4 (below 36 inches).—Calcareous clay mottled yellow and grey, lying over basalt.

This soil forms deep cracks in dry weather, and is often marked by puffs of darker soil, more friable and more intensely cracked than elsewhere. These puffs are analogous to those found in the "crabhole" areas (described later), though they are less well developed here than in the true crabhole areas, and are only occasionally calcareous on the surface. The association of thistles with this type of soil may be due either directly or indirectly to its relatively high lime status, or to the self-mulching tendency

of the soil; thistles are in fact found especially on the puffs, which have these properties best marked. The thistle zone is also more fertile than the lower slopes, no doubt because the soil has been constantly enriched by the addition of the finer particles formed from the weathering of the basalt and washed off the stony rise.

The result of the addition of clay by this process is that the thistle-zone soils are high in clay even though the neighbouring soils on the rises and on the slopes may be sandy. Thus, the lightest sample taken of this type contained only 40 per cent. of total sand in the top 6 inches, compared with 49 per cent. in the top 9 inches of the soil on the corresponding rise 7 yards away, and 69 per cent. in the top 9 inches of the soil on the slopes 25 yards lower down (Type 4). Besides the addition of clay it is likely that the thistle zones are unique in receiving water by seepage as well as by run-off, and this may be responsible for their relatively high base status.

Type 4.—Low SLOPES (lighter type). (Sample numbers beginning 0 . . .)

This and the next type are the normal soils of the area. They are found wherever the land has a gentle slope and is neither rocky nor swampy. The profile of this lighter type may be generalized as follows:—

Horizon 1 (0 to 8 inches).—Non-coherent grey or light grey sandy loam, often lighter in colour below 2 inches. pH about 5.5. Change to heavier underlying soil often sharp.

Horizon 2 (8 to 14 inches).—Grey sandy clay; this is transitional between the surface and the next horizon, and may occupy less than 6 inches. pH about 6.5.

Horizon 3 (14 to 30 inches).—Grey heavy plastic clay, drying to columnar structure. pH rises from 7 to 7.5 in the upper layers to about 8 at the 24-inch level, at which a yellowish colour appears.

Horizon 4 (30 to 70 inches, or until rock is reached).—Greyish-yellow calcareous clay, with a maximum of  $\text{CaCO}_3$  in both soft and nodular forms at 36 inches. pH value 8.3 to 8.7; below 36 inches yellow-grey mottling is common. An exposed profile of this soil in a trench shows the greyish-yellow clay interspersed with brown and black streaks along cracks occupied by old roots. Roots were seen throughout this horizon. This clay is plastic except where lime content is fairly high. Bedrock is usually reached at a depth of between 5 and 8 feet.

The depth of the lighter soil of the surface is variable, being usually from 5 to 9 inches where this type is best developed but rising to 12 to 18 inches on the lower and gentler slopes of Mount Gellibrand itself. Buckshot nodules of iron oxide, up to 5 mm. diameter, are often seen on the surface of these soils, and are in fact fairly generally distributed over the plains and swamps to the extent of 1 or 2 per cent. through all horizons, including calcareous subsoils. This soil type is characteristic of the gentler slopes to the west, south, and east of Mount Gellibrand, and extends uniformly over considerable areas where Mounts Gellibrand and Pleasant merge into the plains. On the northern

side of the cone, however, at a little over 2 miles from the summit, the normal soil of the slopes is a heavier type, and is described here as Type 5.

Type 5.—LOW SLOPES (heavier type). (Sample numbers beginning 00 . . .)

The profile of this type differs from that just described in having less sand. The surface soil is a dark grey clay loam or light clay which dries to form intractable clods; below 8 inches it passes to a grey heavy clay, and the subsoil is very similar to, though less sandy than, that of Type 4. The pH of the surface soil, however, is rather higher than that of Type 4 (about 6.0). This soil has been relatively little affected by the sand thrown up by the volcano, and appears to be typical of the heavy, infertile grey clays that are common in this part of the Western District. The figure of 50 per cent. sand was arbitrarily taken to separate the light soils (Type 4) from the heavy soils (Type 5) for mapping, though there is a steady transition from one type to the other. This value may be justified by two facts:—(a) that the degree of cracking of the soil becomes marked when there is less than 50 per cent. of sand, (b) that this line also marks off the "crabhole" areas (which, in Turkeith, lie entirely to the north of it).

(b) *Swamp Soils.*

Large areas of soil have been developed under conditions of periodical waterlogging. These soils may be classified as two "complexes," here called "pan and bank" and "crabhole."

*Pan and Bank complex* (Sample numbers beginning 1 . . .).

These areas consist of pans of grey clay (Type 6, below) separated by narrow banks in which the surface soil is of similar texture to the adjacent low slope. The axes of the pans may vary from 1 to 50 yards in length, while the banks are a yard or two across and rise about a foot above the level of the pans. Every intermediate stage is represented from normal low slope to normal pan and bank; there are areas where the banks are wide in proportion to the pans, and such half-developed forms of the complex are mapped separately. They are more poorly drained than the normal slopes, and tussocks of *Poa caespitosa* are common in the hollows. At the other extreme there are low-lying swamps which consist entirely of the grey clay pan, without any bank.

Type 6.—GREY CLAY OF SWAMPS.

Horizon 1 (0 to 6 inches).—Steely grey clay, with rusty streaks; drying to hard clods.

Horizons 2, etc.—Grey heavy clay, as with Types 4 and 5, passing to calcareous clay at about 30 inches.

Since the soils of the slopes in the north of the area (Type 5) are as clayey as the swamps, there is little or no contrast in texture between pans and banks in this sector, though there is a marked contrast in their flora. On the south of the mountain, however, the sandy banks are loams or sandy loams while the pans are light or medium clays. When a trench is dug through this complex it is seen that the bank is a layer of the lighter soil resting on a subsurface of clayey soil like that of the pan (see Fig. 2). Table I. shows that the texture of the bank resembles that of the neighbouring low-slope. The aerial photographs (Plate V., upper photograph) reveal that the pans are elliptical, with their longer axes at right angles to the line of flow of water during the winter. Owing to the impervious nature of the subsoil, this swampy complex occurs not only on the actual basins but also on patches of level, higher ground.

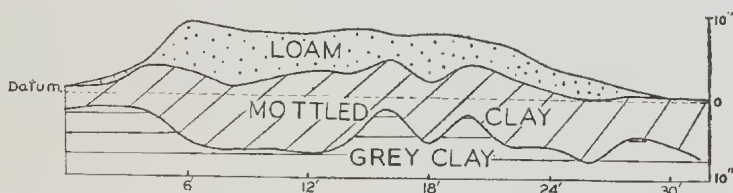


Fig. 2. Section through Pan-and-Bank Complex.

This formation is presumably due to the sorting action of water. Since cultivation destroys the complex it is not surprising that it has not been described elsewhere.

TABLE I.—SANDINESS OF SOIL OF BANKS AND CORRESPONDING PANS, COMPARED WITH NEIGHBOURING LOW SLOPES.

Pan and Bank Sample.	Bank.		Pan.		Nearest low slope	
	Depth inches.	Total Sand.	Depth inches.	Total Sand.	Depth inches.	Total Sand.
160-1 .. ..	0-3 3-10	% 70 46	0-8 8-20	% 46 41	0-8 ..	% 64 ..
170-1 .. ..	0-10 10-18	62 39	0-12 12-24	29 26	0-6 ..	59 ..

Although the soils on the slopes are here described as differing from the non-calcareous swamp soils, the profiles of all three types 4, 5, and 6 are similar in many features such as the presence of "buckshot" (iron oxide concretions) and the level of the calcareous layer; the flora of a swamp that has been drained is similar to that of the slopes around it. The absence of a well-marked difference between the profiles of soils of these types



is probably due to the fact that drainage has been poor even on the slopes because of the impermeability of the subsoil—i.e. the slopes have only “surface” drainage, or run-off. The presence of buckshot throughout these profiles also seems to reflect their liability to periodical waterlogging. Any genetic account of the soils of the plains would have to treat the low-slope types and the pan-and-bank swamps as one group as contrasted with the stony-rise and crabhole types.

*Crabhole Complex* (Sample numbers beginning 2 . . .).

The “crabhole” type of formation is found in certain swampy patches, almost all of which lie on the northern margin of the surveyed area, three miles or more from the top of Mount Gellibrand. These areas consist of alternate puffs and depressions, the pattern of which is well shown in the lower photograph of Plate V. The surface soil of the puffs has a “self-mulching” tendency; that is, it crumbles in dry weather into loose structural units, which are cubical with a side of about 1 centimetre. At the same time, deep and wide cracks are formed. The soil is calcareous; when it is dry and ground up its colour is grey to dark grey; but in the field it often looks black especially along the cracks. The puffs are roughly circular, normally about 3 feet across, and the centre of each may be 6 or 12 inches higher than the margin. In patches of well-marked crabholes, each puff is separated from its neighbour by a flat depression, 3 to 6 feet across. The soil of the depressions contains more sand than that of the puffs. It is grey to dark grey, and it also cracks in dry weather, but is not calcareous and has no self-mulching tendency but dries into hard clods. The far greater volume occupied per unit mass by the soil of the puffs, as compared with the soil of the depressions is easily shown by means of the post-hole auger; it is necessary to remove about twice the weight of soil from the depression as from the puff in order to reach a depth of 1 foot. The following profiles may be taken as typical:—

Type 7.—CRABHOLE PUFF—

Horizon 1 (0·6 inches).—Grey clay, containing calcium carbonate in both soft and concretionary form. Sticky when wet, drying to cubical granular structure.

Horizon 2 (6·36 inches).—No definite transition between this and horizon 1, but structure becomes less definite from the surface downward. Yellower tendency at bottom.

Horizon 3 (36-bedrock).—Greyish, yellow calcareous clay, with sharp transition from horizon 2. This is identical with horizon 4 of Type 4.

Type 8.—CRABHOLE DEPRESSION—

Horizon 1 (0·4 inches).—Grey to dark grey clay, non-calcareous and of cloddy structure.



Horizon 2 (4-27 inches).—Grey to dark grey heavy clay, with yellowing tendency at bottom.

Horizon 3 (27-bedrock).—Identical with horizon 3 above, and continuous with it, as shown in Fig. 6.

In a series of surface samples (0 to 3 inches) which were taken at 8-inch intervals from the centre of a typical puff to the corresponding depression, the pH value was found to change steadily from 7.9 at the centre to 6.9 2 feet away down to 5.8 4 feet away. Below 30 inches, however, the subsoils are identical with each other and with the deep subsoils of the other types—viz., greyish-yellow, somewhat calcareous clay with occasional bands of more calcareous nature with limestone concretions, extending down to the parent rock.

It may be suggested that, in view of the fact that the various types 1, 2, and 3 are essentially derived from basalt, and that types 5, 7, and 8, though affected in this area by tuff, are very similar to soils in analogous situations lying on basalt and unaffected by tuff, it is desirable that the unqualified term "basalt soil" should disappear from scientific literature.

#### B. SOILS OF THE MOUNTAIN.

The lower and gentler slopes of Mount Gellibrand, and most of the slopes of Mount Pleasant, carry the low-slope type of soil in which the loamy character of the surface soil extends to about 12 inches. Halfway up Mount Gellibrand, however, the slope becomes steeper and the soil changes within a few yards to a dark chocolate type of high fertility, as follows:—

Type 9.—MOUNTAIN SOIL (Sample numbers beginning 41 . . . and 5 . . .)—

Horizon 1 (0-8 inches).—Dark chocolate clay loam to clay, rich in organic matter and quite friable.

Horizon 2 (8-16 inches).—Dark brown friable clay with fragments of tuff.

Horizon 3 (16-25 inches).—Brown or pinkish calcareous clay, with considerable tuff.

Though horizons have developed in this soil, the presence of tuff close to the surface, and of active minerals like augite in the fine sand fraction of the surface itself, shows that the type is much less mature than the normal soil of the plain or of the lower part of the mountain. This relative immaturity is probably due to continual erosion; the erosion in this case is of the whole surface soil—including sand—as contrasted with the washing away of fine fractions only from the stony rises. Calcium carbonate is sometimes very copious in the subsoils of this type, reaching over 40 per cent. in one case. This may contribute to the relatively good permeability of the subsoil. Patches of soil occur with a surface of heavy clay texture and pH over 7; such cases are obviously due to excessive erosion.

## V. Chemical and Physical Analyses of the Soils.

### A. MECHANICAL ANALYSES.

Complete mechanical analyses were carried out on selected profiles from each type of soil. The details are given in Tables III. to IX., in which the percentages are in terms of oven-dry soil. The figures have also been recalculated to a basis of sand + silt + clay = 100, and the results of individual samples are plotted in triangular form in Figs. 4 and 5, while mean figures for each type are collected in Table II., and plotted as a summation curve in Fig. 3. It will be seen that the texture of the subsoil is a medium or heavy clay in most cases; the separation of types from one another must rely on differences between surface soils.

Type 4 has the lightest texture; although this includes any low-slope soil of more than 50 per cent. sand, the normal soil in the region covered by this type has at least 60 per cent. of sand, and the texture is loam or sandy loam. The stony-rise loams are next in increasing order of clay; although some of these contain enough clay to fall into the class of clay loams, the high content of organic matter causes them to have a loamy feel. The surface soil of the bank in the complex named "pan and bank" has a texture similar to that of the neighbouring slopes.

The soils of the mountain vary over a considerable range of texture; here again the organic matter contributes to increase the friability. These soils also include those that are highest in silt.

Of the remaining types, one may note that the crabhole puffs are higher in clay than any other type—this is not surprising if it is correct to regard the puff as an old subsoil. The other surface soils are mostly clays of varying heaviness.

It is interesting to note that, if the mountain soils are excluded, all the soils plotted here (with two unimportant exceptions) lie in the band of 10 to 20 per cent. of silt.

The texture of the subsoils (Fig. 5) calls for little comment. The greater sand content in the subsoils of Type 4 is apparently not enough to improve their permeability over that of the other subsoils. The subsoil of profile 006 (Type 5) is exceptionally sandy; other subsoils of this type, although not completely analysed, have much less sand than this.

The amounts of gravel in the various types are in most cases not recorded. The surface soils of the stony rises are always stony, as are those of the mountain which are derived from basalt. Among the maturer types on the plain, buckshot gravel is general from surface to deep subsoil, but it amounts only to about 2 per cent. of the field sample. The other source of material coarser than 2 mm. is an occasional concretion of calcium carbonate in the subsoil at or below a depth of 3 feet.

TABLE II.—AVERAGE COMPOSITION OF SOIL TYPES IN TERMS OF SAND + SILT + CLAY = 100.

Soil Type.			Coarse Sand.	Fine Sand.	Silt.	Clay.
1	..	..	18	40	16	26
2	..	..	16	29	16	39
3	..	..	10	22	10	52
4	..	..	27	41	17	15
5	..	..	18	20	11	51
6	..	..	8	22	17	53
7	..	..	6	18	15	61
8	..	..	11	27	17	45
9	..	..	10	30	20	40

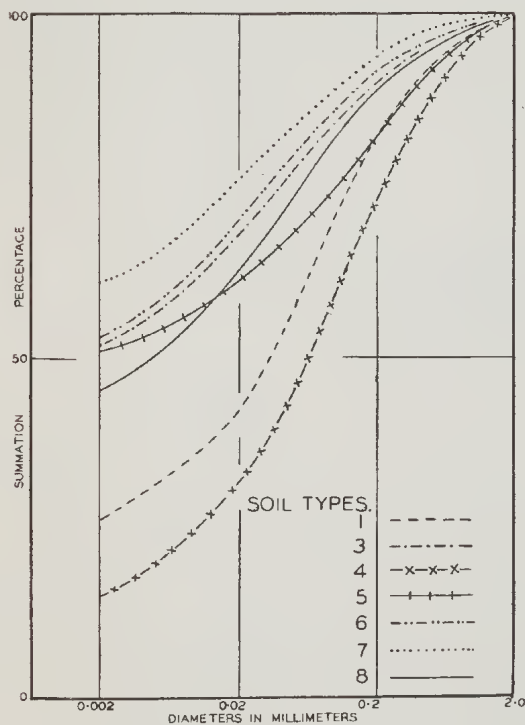


Fig. 3. Summation Curves, illustrating average Mechanical Analysis of the Surface Samples of the Various Soil Types.

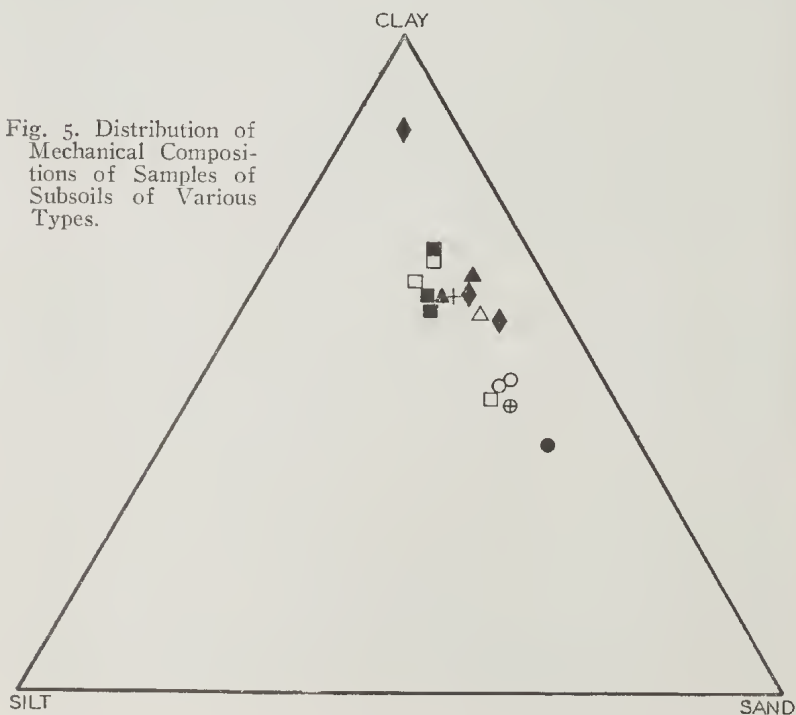
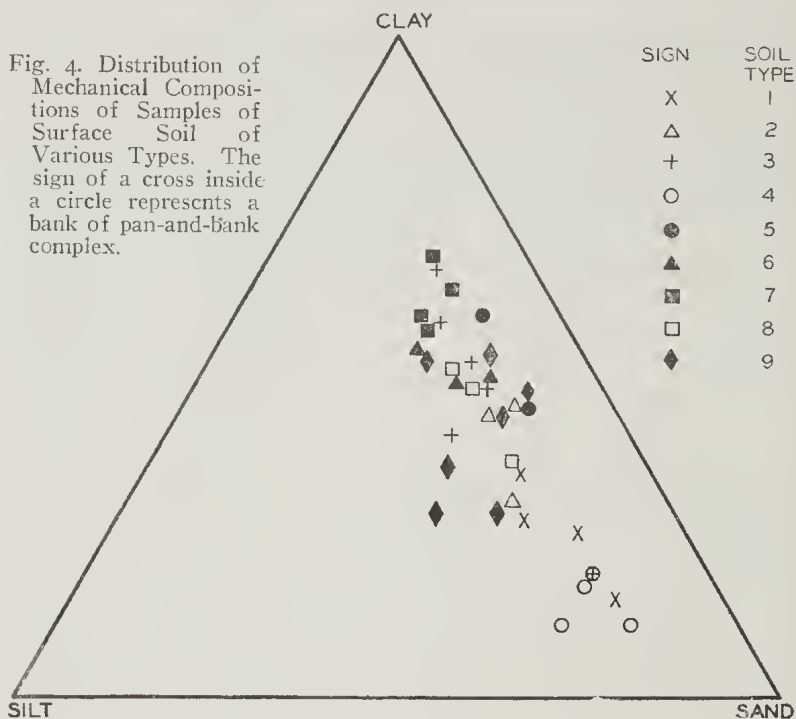


TABLE III.—MECHANICAL ANALYSES OF SOILS OF TYPES 1 (STONY RISE BROWN LOAM) AND 2 (STONY RISE CLAY).

Soil No.	..	4001	401	4011	404	471	472	475	..
Type	..	1	1	1	1	2	2	2	..
*Horizon	..	a	a	a	a	a	a	a	b
Depth (inches)	..	0-9	0-8	0-5	0-6	0-5	0-3	0-6	12-18
Coarse sand	..	11.7	12.1	26.8	15.8	17.3	15.9	10.9	7.0
Fine sand	..	36.8	32.4	36.6	41.2	23.3	22.1	35.2	22.2
Silt	..	18.3	15.1	12.2	13.2	10.7	15.5	18.9	10.5
Clay	..	24.8	30.5	13.7	23.7	41.0	40.2	27.5	55.6
Carbon	..	3.31	4.68	4.35	..	2.86	..	3.28	..
Nitrogen	..	.38	.52	.48	..	.252	..	..	..
CaCO <sub>3</sub>	..	..	..	..	..	..	..	..	..
pH	..	5.4	5.8	5.3	5.6	5.7	6.0	5.7	6.4

\* The letters a, b, . . . . . g used in these tables refer simply to the order of sampling of the various horizons, a being the first and g the seventh horizon taken in a profile. The letters are not meant to suggest any parallel with the technical meanings of A, B, and C horizons.

TABLE IV.—MECHANICAL ANALYSES OF SOILS OF TYPE 3 (THISTLE ZONES).

Soil No.	..	..	302	305	..	..	307	31	311
Horizon	..	..	a	a	b	c	a	a	a
Depth (inches)	..	..	0-6	0-8	8-22	22-30	0-8	0-9	0-6
Coarse sand	..	..	6.5	8.2	8.4	8.5	3.8	16.8	13.2
Fine sand	..	..	29.3	16.7	15.9	16.8	16.1	18.5	18.6
Silt	..	..	13.6	15.0	12.3	11.9	11.1	21.7	13.7
Clay	..	..	44.2	53.7	57.5	58.2	59.4	38.4	47.8
Carbon	..	..	..	1.98	..	..	2.26	..	..
Nitrogen	..	..	..	.130	..	..	.215	.211	.189
CaCO <sub>3</sub>	..	..	..	..	..	..	2.5	..	..
pH	..	..	6.0	6.4	6.6	6.7	8.0	7.0	6.5

TABLE V.—MECHANICAL ANALYSES OF SOILS OF TYPE 4 (LOW SLOPES, LIGHTER TYPE).

Soil No.	..	..	01	..	..	0120	014	..	..	..
Horizon	..	..	a	e	f	a	a	b	c	d
Depth (inches)	..	..	0-4	12-16	16-20	0-9	0-7	7-16	16-30	30-42
Coarse sand	..	..	21.9	22.9	13.6	33.3	22.7	12.6	16.9	17.9
Fine sand	..	..	40.7	26.4	24.8	38.0	39.9	29.4	20.5	20.3
Silt	..	..	17.0	10.8	13.1	12.8	20.9	16.1	13.9	12.0
Clay	..	..	17.0	37.6	44.9	10.6	10.4	38.6	45.5	46.0
Carbon	..	..	1.88	..	..	0.85	1.01	1.02	..	..
Nitrogen	..	..	.154	..	..	..	.084	.098	..	..
Calcium carbonate	..	..	..	..	..	..	..	tr.	tr.	tr.
pH	..	..	5.8	6.5	7.5	5.6	5.4	6.4	7.6	7.8

TABLE VI.—MECHANICAL ANALYSES OF SOILS OF TYPE 5 (LOW SLOPES, HEAVIER TYPE) AND OF PAN-AND-BANK COMPLEX ADJOINING THEM.

Soil No.	..	..	002	006	..	..	12	180	..
Type	..	..	Slope	Slope	..	..	Pan	Bank	..
Horizon	..	..	a	a	b	c	a	a	b
Depth (inches)	..	..	0-6	0-7	7-24	36-42	0-12	0-7	7-14
Coarse sand	..	..	5.3	28.5	26.9	15.4	5.0	6.6	5.7
Fine sand	..	..	25.7	14.0	14.5	33.5	19.0	22.3	20.1
Silt	..	..	9.9	10.3	12.0	11.3	20.3	11.0	8.4
Clay	..	..	56.2	41.8	42.8	36.5	51.4	55.9	61.8
Carbon	..	..	1.64	1.33	1.04	..	..	1.80	1.43
Nitrogen	..	..	.131	.096	.093	..	.138	.176	..
Calcium carbonate	..	..	..	..	..	0.2	..	..	..
pH	..	..	6.1	6.0	7.0	8.0	7.0	6.6	6.5

TABLE VII.—MECHANICAL ANALYSES OF PAN-AND-BANK COMPLEX IN AREA SURROUNDED BY TYPE 4.

Soil No.	..	..	170 (Bank)	..	..	..	171 (Pan)	..	..
Horizon	..	..	a	b	c	e	a	b	c
Depth (inches)	..	..	0-10	10-18	18-36	54-60	0-12	12-24	24-30
Coarse sand	..	..	27.3	18.0	17.3	6.8	10.6	10.2	9.1
Fine sand	..	..	35.9	21.0	22.4	12.4	20.8	18.7	14.7
Silt	..	..	15.2	12.1	13.6	13.2	17.3	17.5	13.8
Clay	..	..	17.7	46.0	42.0	59.9	46.7	49.1	60.1
Carbon	..	..	1.67	1.39	..	..	..	..	..
Nitrogen	..	..	.118	.114	..	..	.117	..	..
Calcium carbonate	..	..	..	..	..	3.9	..	..	..
pH	..	..	5.3	5.5	6.5	8.2	6.8	7.2	7.6

TABLE VIII.—MECHANICAL ANALYSES OF SOILS OF TYPES 7 AND 8 (CRABHOLE COMPLEX: IN ALL THREE CASES THE TYPE 7 AND CORRESPONDING TYPE 8 PROFILE WERE TAKEN WITHIN 3 FEET OF EACH OTHER).

Soil No.	..	260	..	..	261	..	..	280	..	281	..
Type	..	7 (Puff)	..	..	8 (Depres- sion)	..	..	7 (Puff)	..	8 (Depres- sion)	..
Horizon	..	a	b	c	a	b	c	a	b	a	b
Depth (inches)	..	0-4	4-12	12-30	0-4	4-20	20-27	0-8	8-20	0-8	8-20
Coarse sand	7.1	7.2	6.1	9.3	5.8	4.9	7.8	8.2	15.5	13.4	13.4
Fine sand	17.2	17.5	14.5	24.7	17.0	14.1	15.3	13.6	29.7	23.4	23.4
Silt	11.4	13.9	13.0	15.9	16.0	16.4	16.3	14.6	16.6	15.3	15.3
Clay	59.5	56.5	53.3	44.5	56.9	59.8	51.7	50.3	34.1	43.3	43.3
Carbon	1.08	0.81	..	1.96	1.34	..	1.01	0.78	1.68	..	..
Nitrogen	.114	.076	..	.164	.115	..	.198	.081	.144	..	..
CaCO <sub>3</sub>	0.3	0.8	9.8	..	..	..	4.5	10.7	..	..	..
Rubble (field sample)	..	..	..	..	..	..	..	..	..	..	..
pH	..	8.0	8.4	8.7	6.4	7.1	7.6	8.3	8.6	6.4	7.2



TABLE VIII—continued.

Soil No. ..	270	..	..	..	..	..	271	..
Type ..	7 (Puff)	..	..	..	..	..	8 (Depres- sion)	..
Horizon ..	a	b	c	e	f	g	a	b
Depth (inches) ..	0-7	7-26	26-41	54-66	66-90	120	0-8	8-24
Coarse sand ..	3.0	4.5	4.2	4.0	4.6	0.9	5.6	3.6
Fine sand ..	14.1	13.2	12.7	7.2	15.3	9.6	23.9	16.2
Silt ..	10.8	11.7	10.7	9.2	10.5	11.0	16.7	11.8
Clay ..	58.0	57.1	59.8	48.6	65.7	74.7	46.3	62.9
Carbon ..	2.19	1.19	0.72	..	..	..	3.11	1.46
Nitrogen ..	.247	.149	..	..	..	..	.278	.110
CaCO <sub>3</sub> ..	9.0	10.6	11.3	30.0	0.6	0.8	..	..
Rubble (field sample) ..	..	5	7	11	..	..	..	..
pH ..	8.1	8.6	8.5	8.6	8.4	8.2	6.9	7.6

TABLE IX.—MECHANICAL ANALYSES OF TYPE 9 (MOUNTAIN SOIL).

Soil No. ..	411	412	417	..	..	419	..	50	53	56	..
Horizon ..	a	a	a	e*	d	a	b	a	a	a	b
Depth (inches) ..	0-8	0-8	0-6	12-20	20-26	0-8	8-15	0-6	0-8	0-5	27-33
Coarse sand ..	8.6	7.7	7.0	14.0	9.8	5.0	3.2	16.8	6.7	9.8	1.2
Fine sand ..	28.5	17.6	25.1	30.9	19.7	36.1	29.7	28.5	26.4	29.1	2.2
Silt ..	27.0	18.8	21.9	21.3	12.4	9.8	8.2	21.5	11.6	13.8	3.4
Clay ..	24.4	45.6	29.8	24.8	50.0	43.9	54.3	25.6	48.5	40.4	44.2
Carbon ..	..	6.45	8.40	..	..	..	..	..	..	3.75	..
Nitrogen ..	..	.52	.64	..	..	..	..	.262	..	.340	..
CaCO <sub>3</sub> ..	..	..	..	..	..	..	..	..	..	..	47.0
pH ..	5.8	6.0	5.8	6.8	7.0	6.5	6.9	5.9	6.1	6.4	8.8

\* Tuff band.

## B. HYDROCHLORIC ACID EXTRACT.

Representative soils were extracted with boiling hydrochloric acid as in the International method. Analyses of these extracts are collected in Table X., from which the following conclusions may be drawn:—

- (a) The *calcium* content is correlated with the state of saturation of the clay. In the non-calcareous soils there is little difference between the calcium extracted by hydrochloric acid and that extracted by ammonium acetate (exchangeable calcium).
- (b) *Potash* is, as usual, highly correlated with clay; the light, leached soils of Type 4 contain only small amounts, and the immature soils of Type 1, on the stony rises, also yield relatively little to the hydrochloric acid, although they contain good reserves of potash in their primary minerals. All the heavier types contain ample potash.

(c) *Phosphorus* is low or very low in the mature soils; the basalt of this area, like the other basalts of the Western District, contains normal quantities of  $P_2O_5$ —viz., .35 per cent. of the rock; but only the immature soils of Types 1, 2, and 9 are well provided with phosphorus. It is possible that the contrast in fertility between the stony rises and the slopes and swamps has been increased by the fact that grazing animals tend to "camp" on the rises; but the very low figures of the mature soils require further study.

TABLE X.—HYDROCHLORIC ACID EXTRACTS.

—		Sample Number.	Depth.	CaO.	MgO.	K <sub>2</sub> O.	P <sub>2</sub> O <sub>5</sub> .	Mn.
Type 1 (Stony rise brown loam)	..	4001a	0-9	..	..	.16	.125	..
		401a	0-8	..	..	.31	.106	..
		4011a	0-5	.21	.49	.25	.127	.10
		408a	0-3	.26	.39	.10	.116	..
Type 3 (Thistle zone)	..	307a	0-8	3.60	1.04	.59	.046	..
		31a	0-9	.65	.59	.50	.035	..
		311a	0-6	..	..	.28	..	..
Type 4 (Lighter low slopes)	..	014a	0-7	..	..	..	.014	..
Banks of swamps surrounded by Type 4	..	09a	0-8	.05	..	.10	.004	.017
		11a	0-6	.07	.06	.11	.005	..
		170a	0-10	.08	.08	.12	.011	..
		170b	10-18	.18	.25	..	.017	..
		170d	40-48	..	..	.23	.014	..
Type 6 (Clay pan of swamps)	..	171a	0-12	.30	.52	.37	.015	.041
		13a	0-9	..	..	.38	..	..
		180a	0-7	.19	.56	1.01	.025	..
Type 7 (Crabhole puff)	..	260a	0-4	..	..	.77	.022	..
		270a	0-7	4.94	.90	.98	.046	..
		270b	7-26	5.76	.85	1.02	.027	..
		270c	54-66	..	..	.69	.016	..
		280a	0-8	..	..	.44	.020	..
		..	..	..	..	..	..	..
Type 8 (Crabhole depression)	..	23a	0-4	.87	.72	.84	.051	.047
		271a	0-8	.48	.54	.72	.030	..
Type 9 (Mountain soil)	..	417a	0-6	.72	.41	.21	.135	.695
		50a	0-6	..	..	.23	.071	..
		56a	0-5	.28	.45	.53	.048	..

## C. CARBON AND NITROGEN.

Carbon was estimated by Tiurin's method, which consists of oxidizing a half-gram sample of finely ground soil with standard dichromate in 1:1 sulphuric acid and titrating the residual dichromate. The organic carbon was calculated using the figure 1 ml. normal oxidizing agent equals 3.45 mg. carbon. This is the figure proposed by Allison (1935) for a similar method, but comparison of the values obtained for selected soils by dry combustion indicates that these figures are about 5 per cent. too high. Nitrogen was estimated in the usual way.

Individual values are included in the tables of mechanical analyses. The results are collected in Tables XI. and XII.

These show that the immature types 1 and 9 are richer than the others in organic matter, while Type 2 is transitional in this as in other respects between Type 1 and the low slopes. Of the remaining types, though the number of samples is small, it appears that the low slopes (4 and 5) are the poorest, while the crabhole depressions and thistle zones (Types 8 and 3) are richer than the other mature soils.

The mean value of the low-slope types, 0.11 per cent. nitrogen, may be compared with the figure 0.108 per cent. found by Jenny (1930) as the most likely value for nitrogen in a soil under grass in undulating country in a climate of rainfall 22.7 inches, mean temperature 13.5° C., and saturation deficit 0.131 inch (these being the figures for Mooleric station). The carbon-nitrogen ratio generally lies between 9 and 14, with a mean of about 11.

TABLE XI.—DISTRIBUTION OF NITROGEN CONTENT OF SURFACE SOILS.

	Mean.	.05-.10.	.10-.15.	.15-.20.	.20-.25.	.25-.30.	.30-.35.	.35-.40.	.40-.50.	.50-.60.	.60-.70.
Type 1 (Stony rise brown loam) ..	.44	..	..	..	..	..	..	1	1	1	..
Type 2 (Stony rise clay) ..	.25	..	..	..	..	1	..	..	..	..	..
Type 3 (Thistle zone) ..	.19	..	1	1	2	..	..	..	..	..	..
Type 4 (Low slopes, light type) ..	.12	2	2	2	..	..	..	..	..	..	..
Type 5 (Low slopes, heavy type) ..	.11	1	1	..	..	..	..	..	..	..	..
Type 6 (Clay pan of pan and bank complex) ..	.14	..	3	..	1	..	..	..	..	..	..
Type 7 (Puff in crabhole complex) ..	.16	1	1	2	1	..	..	..	..	..	..
Type 8 (Depression in crabhole complex) ..	.22	..	1	1	..	2	..	..	..	..	..
Type 9 (Mountain soils) ..	.44	..	..	..	..	1	1	..	..	1	1

TABLE XII.—DISTRIBUTION OF CARBON CONTENT OF SURFACE SOILS (BY TIURIN'S METHOD).

	Mean.	1.0.	1.0-1.5.	1.5-2.0.	2.0-2.5.	2.5-3.0.	3.0-4.0.	4.0-5.0.	5.0-6.0.	6.0-8.0.	8.0-10.0.
Type 1 ..	4.1	..	..	..	..	..	1	2	..	..	..
Type 2 ..	3.1	..	..	..	..	1	1	..	..	..	..
Type 3 ..	2.1	..	..	..	1	..	..	..	..	..	..
Type 4 ..	1.2	1	1	1	..	..	..	..	..	..	..
Type 5 ..	1.5	..	1	1	..	..	..	..	..	..	..
Type 6 ..	1.7	..	..	2	..	..	..	..	..	..	..
Type 7 ..	1.3	..	3	..	1	..	..	..	..	..	..
Type 8 ..	2.2	..	..	2	..	..	1	..	..	1	1
Type 9 ..	6.2	..	..	..	..	..	1	..	..	..	..

## D. SOLUBLE SALTS.

Several samples were analysed for their soluble salts. Qualitative analyses of extracts of typical soils show that sodium completely dominates the positive ions, while chloride is the most important of the negative ions (especially in the more saline

soils), bicarbonate coming next in order of importance, while sulphate makes up the unimportant remainder. The chloride calculated as NaCl is therefore given as the index of salinity in Table XV.

Appreciable concentrations of salt may occur in the swamps of Type 6, even in the first foot; the surface soils of the low slopes, however, are relatively free from salt, as are those of the swamps of the crabhole type, where leaching of salt is helped by the cracking in summer. Concentrations of salt in subsoils are usually high, especially in the swampy areas. For example, sample 13c, at a depth of 20-26 inches, reaches 0.37 per cent. of sodium chloride. In spite of this salinity, this soil carried a fair growth of the annuals *Trifolium subterraneum* and *Hordeum maritimum* after being drained and top-dressed. A concentration of 0.35 per cent. was also reached at a depth of 24 inches in sample 161, the pan on which the vegetation depicted in Fig. 10 was studied.

These high concentrations of salt even on the slopes show that leaching is not very effective, and this may be connected with the fact that the average rainfall per wet day is low in this part of Victoria.

TABLE XV.—SALT CONTENT OF SOILS.

Low Slopes.			Crabholes.			Clay Pan (Type 6).		
Sample.	Depth.	NaCl per 100,000.	Sample.	Depth.	NaCl per 100,000.	Sample.	Depth.	NaCl per 100,000.
006a	0-7	13	270a	0-7	tr.	13a	0-9	45
006b	7-24	63	270b	7-26	8	13b	9-20	102
006c	36-42	237	270d	41-54	186	13c	20-26	370
014a	0-7	12	270f	66-90	437	161b	8-20	110
014b	7-16	20	271a	0-8	7	161c	20-27	353
014d	30-42	108	271b	8-24	58	171a	0-12	40
014e	60-72	150	271c	28-40	342	171b	12-24	67
019a	0-8	tr.	281a	0-8	10	170a*	0-10	12
019b	8-21	133	22c	15-24	9	170b*	10-18	17

\* Bank corresponding to clay pan sample 171.

#### E. pH VALUES.

Reactions were determined by means of the quinhydrone electrode. The distribution of the pH values of the surface, subsurface, and subsoil is shown in Table XIV. It will be seen that pH values on the acid side of 6 are confined to the lighter surface soils—the stony rise brown loams (Type 1) and the lighter type of low slopes (Type 4), which are more easily leached. The alkalinity of the crabhole puffs (Type 7) is in marked contrast to the slight acidity of the other soils of the area. The next highest figure, 7.0 for the thistle zone soil (Type 3), is significantly higher than that for the adjoining slopes.

The word "subsurface" is used here to correspond roughly to the depth 10 to 24 inches; the pH generally rises by about a unit in going through this section, but the mean value lies close to 7.0 for most soil types, except Type 7 which is calcareous throughout. The deeper, calcareous yellow subsoils also have a similar reaction whatever the soil type may be. The frequency of pH values above 8.5 in the deep subsoil may well be due to exchangeable sodium.

TABLE XIV.—DISTRIBUTION TABLE OF pH VALUES  
(QUINHYDRONE ELECTRODE).

				Mean.	4.5-5.0.	5.0-5.5.	5.5-6.0.	6.0-6.5.	6.5-7.0.	7.0-7.5.	7.5-8.0.	8.0-8.5.	8.5-9.0.
Type 1 (Stony rise brown loam)—													
Surface	..	..	..	5.5	1	6	6	1	..	..	..	..	..
Type 2 (Stony rise clay)—													
Surface	..	..	..	5.8	..	..	4	2	..	..	..	..	..
Subsurface	..	..	..	6.8	..	..	..	1	..	1	..	..	..
Type 3 (Thistle zone)—													
Surface	..	..	..	7.0	..	..	..	3	1	3	1	1	..
Subsurface	..	..	..	7.3	..	..	..	..	2	..	3	..	..
Subsoil	..	..	..	8.1	..	..	..	..	..	1	..	3	1
Type 4 (Light low slope)—													
Surface	..	..	..	5.8	..	2	10	7	..	..	..	..	..
Subsurface	..	..	..	7.4	..	..	..	..	1	2	3	..	..
Subsoil	..	..	..	8.2	..	..	..	..	..	..	2	3	2
Type 5 (Heavy low slope)—													
Surface	..	..	..	6.3	..	..	1	7	3	..	..	..	..
Subsurface	..	..	..	6.9	..	..	..	1	..	2	..	..	..
Subsoil	..	..	..	8.0	..	..	..	..	..	..	..	1	..
Bank of Pan and Bank complex— (Bank similar to Type 4)—													
Surface	..	..	..	5.9	..	1	..	3	..	..	..	..	..
Subsurface	..	..	..	6.8	..	..	..	1	..	..	1	..	..
Subsoil	..	..	..	8.2	..	..	..	..	..	..	..	2	..
Pan (Type 6)—													
Surface	..	..	..	6.5	..	..	2	2	7	1	..	..	..
Subsurface	..	..	..	7.3	..	..	..	..	..	3	2	..	..
Subsoil	..	..	..	8.1	..	..	..	..	..	..	1	3	1
Type 7 (Crabhole Puff)—													
Surface	..	..	..	8.0	..	..	..	..	..	..	3	3	..
Subsurface	..	..	..	8.5	..	..	..	..	..	..	..	2	3
Subsoil	..	..	..	8.5	..	..	..	..	..	..	..	1	2
Type 8 (Crabhole Depression)—													
Surface	..	..	..	6.5	..	..	..	3	2	..	..	..	..
Subsurface	..	..	..	7.2	..	..	..	..	1	2	2	..	..
Subsoil	..	..	..	8.1	..	..	..	..	..	..	1	1	1
Type 9 (Mountain soil)—													
Surface	..	..	..	6.0	..	1	6	8	1	..	..	..	..
Subsurface	..	..	..	6.9	..	..	..	1	3	..	..	1	..
Subsoil	..	..	..	8.8	..	..	..	..	..	..	..	..	2

#### F. EXCHANGEABLE CATIONS.

The analyses of the exchangeable cations of representative samples are given in Table XV. It will be seen that magnesium is the dominant ion in most of the mature types, while calcium



is generally second in order of importance. This predominance of magnesium is invariable at the deeper levels, and is also well marked on the heavy surface soils 006a and 180a, though on the lighter surface soils (014a, 019a), including the immature soils (4011a, 408a), calcium is more important. Definite predominance of calcium seems to be confined, among the mature soils, to the calcareous puffs of the crabhole type (270a, 280a), though even here one of the two samples analysed shows quite a high figure for magnesium. Two samples from types fairly high in organic matter (305a, 56a), show calcium and magnesium in equivalent amounts.

Sodium is present in amounts varying from small values up to 14 per cent. of the total cations in the surface soil, and exceeds 20 per cent. in three of the deep calcareous subsoils (014e, 11e, 270e), all of which occur on the poorly drained plains and are quite saline. In the better drained and less saline subsoil from the mountain (56b), sodium reaches only 10 per cent. The lowest percentages of sodium are found in the well-drained soils on the stony rises (4011a, 408a) and on the friable and deeply cracked "puffs" of the crabhole and thistle-zone types (270a, 280a, 305a).

Potassium makes up only a small proportion of the total of exchangeable cations, and this proportion is higher in the surface than in the subsoil. If the doubtful assumption is made that exchangeable potassium is a measure of available potassium, then the amount of this potassium in the soils analysed is at a satisfactory figure for fertility.

#### ORIGIN OF HIGH VALUE FOR EXCHANGEABLE MAGNESIUM AND SODIUM.

The percentage of magnesium among the exchangeable cations is very high when judged by the standards of other countries. The basalts of the Western District certainly contain considerable amounts of magnesium, which may reach 11 per cent. of the rock (as  $MgO$ ). But this fact can hardly be accepted as the reason for the predominance of magnesium among the exchangeable cations in a soil that has been so long exposed to the weather. Exchangeable magnesium is in fact high throughout those sections of south-eastern Australia which have the Mediterranean type of climate, whatever the parent material of the soil may have been. The proportions of cations given above are in fact very similar to those found in the course of surveys in the Murray Valley (e.g., Taylor and Penman, 1930) and the high magnesium is found even in Tasmania (Taylor and Stephens, 1935). Prescott (1931, p. 29) commenting on this suggests that "This relatively high proportion of exchangeable magnesium is probably to be related to the accession of magnesium salts to the soil as cyclic salt." The importance of cyclic salt in this part of the Western District is indicated by the occurrence of salt lakes.



While the winter is showery, the rainfall is not very high, and the natural drainage is so poorly developed that salts can accumulate in the subsoil.

There is very little information in the literature as to the connection of high magnesium values with the fertility or the tenacity of the soil. The soils on the slopes (e.g., 006a) and in the non-calcareous swamps (e.g., 180a) to the north of the mount, and in the swamps (e.g., 171a) to the south of the mount, have a poor texture, and dry to very hard clods. There is, however, no evidence that these properties are due to the high Mg; they could be accounted for by the high content of clay of these soils and to their lack of saturation with bases; the more saturated or calcareous soils such as the thistle-zone and crabhole types are much more friable although they are high in clay. Hungarian workers (Kreybig, 1935) have described magnesium soils which are equal in texture to normal calcium soils but which appear to be associated with sensitivity to drought.

TABLE XV.—EXCHANGEABLE CATIONS.

—	Sample Number.	Depth (Inches).	Exchangeable Ions.					pH.	Per cent. Clay.
			Per cent. of Total.				Total in milliequiv. per 100 gm. Oven-dry Soil.		
			Ca.	Mg.	K.	Na.			
Type 1 (Stony rise brown loam)	4011a	0-5	58	29	9	4	9.6	5.3	13.7
	408a	0-3	54	31	10	4	4.1	4.9	..
Type 3 (Thistle zone) ..	305a	0-8	46	48	2	4	39.1	6.4	53.7
Type 4 (Lighter low slopes)	014a	0-7	39	42	8	11	3.6	5.4	10.4
	014b	7-16	30	52	3	15	16.5	6.4	38.6
	014c*	60-72	35	40	1	23	45.0	8.4	56.6
	019a	0-8	51	36	5	8	3.9	6.1	..
	019b	8-21	24	60	4	11	30.0	8.0	..
Bank of Pan-and-bank complex surrounded by Type 4	11c*	39-42	30	46	3	21	38.3	8.6	..
	170a	0-10	45	35	5	14	6.2	5.3	17.7
	170b	10-18	32	40	3	16	20.6	5.5	46.0
	170d*	40-48	35	50	2	13	26.5	8.0	..
Type 5 (Heavier low slope)	006a	0-7	27	57	5	11	23.1	6.0	41.8
	006b	7-24	25	58	3	14	23.6	7.0	42.8
Type 6 (Clay pan) ..	171a	0-12	36	52	3	9	31.9	6.8	46.7
	171c	24-30	36	51	3	10	36.5	7.6	60.1
	180a	0-7	27	56	8	9	24.8	6.6	55.9
	180b	7-14	24	58	7	11	29.5	6.5	61.8
Types 7 and 8 (Crabhole complex)—									
Puff .. ..	270a*	0-7	69	25	4	2	44.6	8.1	58.0
	270b*	7-26	51	39	4	6	42.0	8.6	57.1
	270c*	54-66	15	61	3	21	34.0	8.6	48.6
Depression .. ..	271a	0-8	58	32	4	6	37.4	6.9	46.3
Puff .. ..	280a*	0-8	53	40	2	5	42.4	8.3	51.7
	280b*	8-20	50	40	2	8	50.2	8.6	50.3
	280d*	30-40	36	52	2	10	48.0	8.2	..
Depression .. ..	281a	0-8	37	51	3	9	15.4	6.4	34.1
Type 9 (Mountain soil) ..	56a	0-5	42	43	7	8	25.8	6.4	40.4
	56b*	27-33	38	51	1	10	50.9	8.8	44.2

\* Soils thus marked are calcareous.

Sodium is probably added as sodium chloride in the rain. It is an open question whether the 10 per cent. or so of sodium in the cations of the surface soil plays a part in causing a poor texture, but the deep calcareous subsoils undoubtedly owe their impermeable nature partly to the high amount of replaceable sodium.

#### G. CHEMICAL COMPOSITION OF COLLOIDAL FRACTIONS.

The fraction less than one micron (0.001 mm.) in diameter was isolated from five selected soils. Four of these were dispersed directly by shaking with dilute NaOH, while the calcareous soil 270e was first treated with a slight excess of dilute HCl and then washed free of acid before dispersing with alkali. The suspensions were allowed to settle in tall cylinders for four days, then siphoned off to a depth of 28 cm. from the surface. This treatment was repeated on the residue, and the combined liquids from three such treatments were evaporated to dryness. The solid was then repeatedly washed with  $\frac{N}{50}$  HCl, using a centrifuge, then washed with aqueous alcohol and dried at 105°. While the extraction of colloidal matter by this method was not complete, enough was obtained to justify one in regarding it as a fair sample of the total colloid.

Some of the results of total chemical analysis are given in Table XVIa. Besides the elements reported here, the samples contained considerable magnesium (up to 2 per cent. MgO) but traces only of calcium. This agrees with the general principle that calcium occurs mainly as an exchangeable ion, while magnesium occurs also as a non-exchangeable ion. Titanium is fairly high in the clays, as it is in the parent rocks.

Chief interest, however, attaches to the three main constituents—silica, alumina, and ferric oxide, molecular ratios of which are collected in Table XVIb. The silica-alumina and silica-sesquioxide ratios fall into two classes: the dark brown soil from the stony rise (401a) is much richer in sesquioxides than the other four samples, which are all from profiles of grey, relatively mature soils, and are highly siliceous.

In view of the confused state of soil nomenclature to-day, one would hesitate to assign the more mature soils (types 3 to 8) to any of the great soil groups of the world. While it is probably true, as pointed out by Marshall (1935) that mere silica-sesquioxide ratios give little information as to the true nature of a clay, it is clear that these soils belong to the markedly siliceous class. The existence of a podzolizing process is indicated by the relatively low pH values of the surface soils, by the presence of iron concretions, and by the more siliceous nature of the surface soil (170a) than the subsoil (170c); but these soils are far from being podzols.

The contrast between the relatively ferruginous clay of the rises and the siliceous clay of the slopes and swamps is very interesting. Such a difference must be due either to a different kind of weathering or to the erosion of siliceous surface material from the rises, followed by its deposition on the slopes and swamps. It is possible that the better drainage and the greater content of organic matter on the rises might result in the formation of a less siliceous clay than is formed on the slopes. If this were the case, one would expect to find some of this less siliceous clay deposited also around the edge of the rises in the "thistle zones"; but in fact the clays of this type are typically siliceous (e.g., 305a). If erosion alone is the cause of the difference, one must regard the stony-rise soils as undergoing a process of podzolization, leading to a siliceous surface and a relatively sesquioxidic subsoil; if the siliceous surface were then continually eroded, the resultant soil would be partly a residual subsoil and partly a freshly weathered material derived directly from the basalt. Such soil might have a silica-sesquioxide ratio of about 2, as has the sample here quoted. Whatever be the true explanation of the facts, it is clear that erosion has played, and still plays, an important part in determining the nature of the soil of this area. When the rises have been further reduced in slope as has occurred at some points, eventually the same grey type of soil forms on them as is characteristic of the rest of the plains.

TABLE XVIIA.—CHEMICAL COMPOSITION OF COLLOID FRACTIONS.

Type.	Sample Number.	Depth (Inches).	Per cent.			
			SiO <sub>2</sub> .	Al <sub>2</sub> O <sub>3</sub> .	Fe <sub>2</sub> O <sub>3</sub> .	TiO <sub>2</sub> .
1 .. ..	401a	0-8	42.6	25.3	14.7	1.8
3 .. ..	305a	0-8	49.6	20.4	11.3	1.5
4-6* ..	170a	0-10	49.6	18.9	8.9	3.4
4-6* ..	170c	18-36	49.1	22.2	11.6	2.8
7 .. ..	270c	54-66	51.4	22.5	11.4	1.6

TABLE XVII B.—MOLECULAR RATIOS OF SILICA, ALUMINA, AND FERRIC OXIDE.

Type.	Sample.	Depth (Inches).	SiO <sub>2</sub>	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>
			Al <sub>2</sub> O <sub>3</sub> .	Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> .	Fe <sub>2</sub> O <sub>3</sub> .
1 .. ..	401a	0-8	2.86	2.08	2.7
3 .. ..	305a	0-8	4.12	3.04	2.8
4-6* ..	170a	0-10	4.44	3.41	3.3
4-6* ..	170c	18-36	3.75	2.81	3.0
7 .. ..	270c	54-66	3.89	2.93	3.1

\* This sample is from a bank in pan-and-bank complex surrounded by soil of Type 4.

## H. ANALYSES OF COLOURS.

Table XVIII. contains the analyses of the colours of representative soils of each type. The dry soil was ground to pass a 1 mm. sieve and stuck with duco on to a disc of bristol board. This disc was clamped on to an axis together with four larger discs of standard colours, and the whole was rotated rapidly enough to avoid flickering. The relative areas of the standard discs were varied until a match was obtained. This is the method recommended by Taylor (1935). The standards referred to in Table XVIII. are printed by the Munsell Color Company, and are described by the United States Bureau of Standards as follows:—Black, neutral, 1/-; white, neutral, 9/-; yellow, 8/8; red 4/9.

The table shows the existence of six different colours in the surface soils, viz., 1; 2 and 3; 4; 5 and 6 and 8; 7; 9. Different samples of one type agree very well with one another. The table brings out both the darkness and the brownness of the types richest in organic matter (1, 9). These types are distinguished by having less white than yellow or red. Among the other types which are of various depths of grey, the loamy type 4 has much the lightest colour. The values for type 7 (crabhole puff) give a false impression of its appearance in the field; these figures really represent the mean of a black soil and white calcium carbonate. The contrast between the black subsoils of the thistle zone and the grey subsoils of the other types is also interesting.

TABLE XVIII.—ANALYSES OF COLOURS OF SOIL TYPES.

Type.	Number of Samples.	Percentage of			
		Black.	White.	Yellow.	Red.
Surface Soils—					
1 .. .. .	2	83	2.5	6	8.5
2 .. .. .	3	83	7	5	5
3 .. .. .	4	84	6	5	5
4 .. .. .	3	63	16	10	11
5 .. .. .	2	74	10	8	8
6 .. .. .	1	75	10	9	6
7 .. .. .	3	74	15	6	5
8 .. .. .	3	77	10	7	6
9 .. .. .	6	88	2	4	6
Sub-surface—					
3 .. .. .	2	87	7	3	3
4, 5 .. .. .	3	69	12	11	8

## VI. Note on the Origin of "Crabholes."

The crabhole type of formation here described has been noted in many parts of Australia, sometimes under other names such as "gilgai" "melon-hole", and "Bay of Biscay". It has been mentioned by Prescott (1931, p. 15), who reproduces a section due to H. N. England, of a typical crabhole formation in the

Riverina district of New South Wales. The rough section reproduced here (Fig. 6) is essentially similar to England's.

The biggest areas of the crabhole complex occur in the Wimmera (Victoria) and the Riverina districts, the parent material being an unconsolidated sediment rich both in clay and in calcium. Crabhole formation also occurs directly on the Newer Basalt at Natta Yallock, near Avoca (Victoria), where it occurs on slopes as well as on flats, and often with basalt boulders lying on the surface. The formation in the area described in this paper has developed partly from basalt and partly from the wash from the slopes below the stony rises.

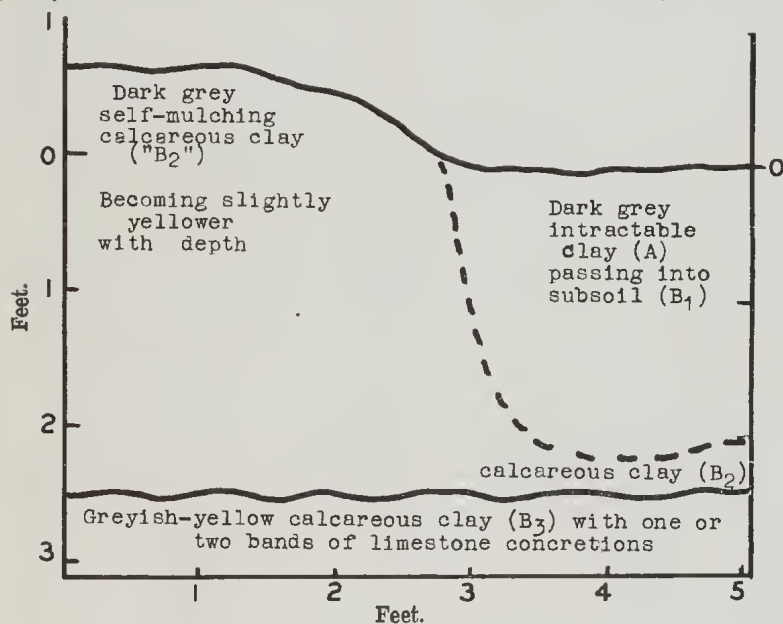


Fig. 6. Section through Crabhole Complex

Prescott points out that the districts in which "crabholes" occur are liable both to drought and to flooding. The climate also has been able to produce only a moderate degree of leaching, so that calcium carbonate is present throughout in the subsoil, and comes to the surface in the puff. Such an association of parent material and climate would be expected to recur in other parts of the world, and it is curious that so few reports of this complex have appeared elsewhere. The structure of the puff type of soil, however, appears to resemble that of the "adobe soils" in the west of the United States of America described by Smith (1933).

While no attempt is here made to put forward a comprehensive theory of the origin of crabholes, some of the data obtained should be useful in helping to solve this problem.



It is an interesting fact that, while swampy patches occur naturally over a considerable part of the area here surveyed, only a small proportion of these patches have given rise to crabhole formation. Apparently, at least two conditions are required to form crabholes on this parent material. Firstly, the proportion of sand in the soil must be below a certain maximum figure; and secondly, where this first condition is satisfied, the swamp must be a basin from which there is no definite outlet. Where the swampy patches occur along a line where water flows during wet periods the complex that is developed is of the "pan and bank" type.

The calcareous nature of the puff indicates that it is really a B horizon which has in some way lost its cover of A horizon and been pushed up. This is conveyed by England's section already referred to, which shows an A horizon only in the depression. This conclusion is reinforced by a comparison of the mechanical analyses of pairs of adjoining puff and depression. The depression is sandier, to a depth of two feet.

Table XVIII. refers to two pairs of puff and corresponding depression in the surveyed area; two other pairs collected by one of the authors are also included for comparison, one from Salisbury (Victoria) being typical of the sedimentary area of the Wimmera, while that from Natte Yallock has already been referred to.

It is noticeable that puffs occur only on soils that are clayey enough to form wide deep cracks in the summer. This is strikingly shown in the Mount Gellibrand area, where the gradual decrease in the concentration of sand in the soil is accompanied by an increasing tendency to crabhole formation in the swamps. As the map shows, the southern and eastern sections are free from "crabholes" and the biggest extent of them is in the north-west, where samples 270 and 271 are typical. The other case quoted—280-281 in the south-western section—must represent the upper limit of sandiness, beyond which crabholes cannot form. In general, the crabhole complex is found only when the surface soil of the surrounding slopes contains less than 50 per cent. of total sand. The sample 280-281, however, is close to slopes containing 30 per cent. of coarse sand and 40 per cent. of fine sand in the surface soil; the higher concentration of clay in this crabhole complex is a good example of the exluviation (see 113) of the finer fractions from the slopes. This patch of crabholes is too small to be given its proper sign on the soil map.

One can draw up some such scheme as the following, to account for the formation: When the soil dries and cracks, pieces of the surface fall down the cracks, adding to the bulk of subsurface and subsoil. When this becomes wet again, it must swell; and now that the subsoil has received extra material, it



will exert pressure sideways, and upwards. In time this subsoil bursts through to form the surface of a "puff", leaving the former A horizon partly in the depression (where it may still be seen) and partly mixed up with the mass of subsoil in which it is lost, since B horizons are generally deeper than A. Vageler (1933) attributes the uniformity of the profiles of tropical and subtropical black earths on clay flats to this mixing up by alternate cracking and swelling. The tendency of the subsoil to swell is shown by the fact that drainage channels (4 inches deep) cut through this land are liable to close up through the appearance of a new puff; and even after the land has been levelled (i.e., the calcareous clay is distributed over all the surface), the puffs still assert themselves, as can be seen if one examines the aerial photograph of a field ploughed and sown to grass several years ago. The depression generally contains more organic matter than the puff; this may be due to the fact that the roots of many plants cannot withstand the cracking of the puffs.

The correlation of *Medicago hispida* with this formation is remarkable. This burr medick is often the only plant to be found growing on the puffs; and the northern paddocks which contain the crabhole areas are also marked by the presence of this burr. It is not known if this association is connected with the marked contrast in pH of the puffs and the other soil types.

TABLE XVIII.—PROPERTIES OF COMPONENTS OF CRABHOLE COMPLEX.

Where Sampled.	Description.	Depth (Inches).	pH.	Sand (Per cent.).	CaCO <sub>3</sub> (Per cent.).	Organic Carbon (Per cent.).
Mooleric ..	Puff ..	0-8	8.3	23	4.5	1.01
	(Sample 280) ..	8-20	8.6	22	10.7	0.78
	Depression ..	0-8	6.4	46	0.0	1.68
	(Sample 281) ..	8-20	7.2	36	0.0	1.01
Turkeith ..	Puff ..	0-7	8.1	17	9.0	2.19
	(Sample 270) ..	7-26	8.6	18	10.6	1.19
	Depression ..	0-8	6.9	30	0.0	3.11
	(Sample 271) ..	8-24	7.6	20	11.	1.46
Salisbury ..	Puff ..	0-7	8.2	20	*	..
	..	7-16	8.2	24	..	..
	Depression ..	0-7	7.1	43	0.0	..
	..	7-24	7.7	30	..	..
Natte Yallock ..	Puff ..	0-2	8.5	18	*	..
	Depression ..	0-2	6.2	34	0.0	..

\* These soils are calcareous, especially that from Natte Yallock.

## VII. Mineralogy of the Sand Fractions.

The gravel fractions (over 2 mm.) and coarse sand fractions (2-0.2 mm.) were examined under the binocular microscope, and in the mountain and stony rise soils, an approximate estimate of the composition of the coarse sand was made by counting the number of grains of each mineral species present in a sample of

200. The percentage of each mineral by volume in the fine sand (0.2-.02 mm.) was determined as described in a previous paper (Nicholls, 1936).

Numerous examples of each soil type were examined, and no significant mineralogical difference in the composition of the fine sand was found between individual samples belonging to the same type, except in type 1 (see Table XIX.), where the high variability is only to be expected. Results are therefore given in Table XX, as an average for the whole type. The samples were taken from varying depths in the soil profile, in some cases a complete profile being examined to a depth of 5 feet. The figures quoted in Table XX., however, are compounded using only one mean figure for each profile; the average for types 4 to 8, for example, is the average of five figures, these being the means of profiles 014, 170-1, 180-1, 270-1, and 280. The amount of sand in the soil changes with depth, but the mineral composition of this sand is remarkably constant (see Table XXI.). One important variation is shown by the number of sponge spicules present, which is high in surface soils and falls rapidly with increasing depth, but since these spicules are organic remains and not soil minerals, they have been omitted in the

TABLE XIX.—MINERAL COMPOSITION OF FINE SAND OF VARIOUS SAMPLES OF TYPE I.

*Number of Grains of Principal Minerals in Sample of 500.*

No. . . . .	400a.	4001a.	4011a.	402a.	403a.	405a.	406a.	408a.	409a.
Quartz . . . . .	275	194	169	228	260	190	261	174	292
Plagioclase . . . . .	73	87	132	93	97	103	74	93	59
Iron oxide . . . . .	50	138	102	71	74	57	61	82	64
Augite . . . . .	44	26	41	76	39	60	39	68	26
Olivine . . . . .	9	18	23	18	4	20	15	23	10
Rock . . . . .	23	35	29	11	21	25	20	20	20

TABLE XX.—AVERAGE PERCENTAGE VOLUME OF IMPORTANT MINERALS IN FINE SANDS.

Soil Type.	1. Stony Rise Loam.		3. Thistle Zone.		4-8. Slope and Swamp Soils.		9. Mountain Soils.	
Quartz . . . . .	50.3	(4.4)	86.8	(0.6)	93.7*	(0.1)	76.6	(2.2)
Plagioclase . . . . .	19.3*	(1.8)	8.7	(1.7)	3.9	(0.2)	10.0	(0.7)
Iron oxide . . . . .	8.4*	(1.5)	1.7	(0.6)	1.2	(0.1)	3.3	(1.0)
Augite . . . . .	12.3*	(1.5)	1.0	(0.1)	Trace		0.4	(0.15)
Olivine . . . . .	2.2	(0.4)	0.8	(0.3)	0.5	(0.05)	1.5	(0.4)
Basalt . . . . .	7.6*	(1.1)	0.3	(0.15)	Trace			
Basaltic glass . . . . .							7.7*	(1.7)

NOTE.—Figures in black type are significantly higher than those for mature soils (Types 4-8).

Percentages significantly the highest for each mineral are marked with asterisk.

Figure in parentheses are the standard errors of the means.

TABLE XXI.—MINERAL COMPOSITION OF FINE SAND OF TYPICAL CRABHOLE PROFILE (270).

*Number of Grains in Sample of 500.*

Horizon No. . . . .	a	b	c	d	e	f	g
Depth . . . . .	0-7".	7-26".	26-41".	41-51".	54-66".	66-90".	120".
Quartz . . . . .	390	} 410	458	462	458	453	{ 392
Plagioclase . . . . .	58						
Iron oxide . . . . .	24	23	20	18	19	30	49
Augite . . . . .	1	..	2	3	4	..	40
Olivine . . . . .	8	9	6	5	4	8	1
Rock . . . . .	..	..	..	..	1	..	6
Zircon . . . . .	5	5	5	5	5	4	..
Tourmaline . . . . .	5	6	3	5	4	4	3
Leucocoxene . . . . .	1	6	5	1	2	..	4
Epidote . . . . .	..	..	..	..	1	..	5
Sponge spicules . . . . .	8	2	1	1	2	1	..

calculation of results. Samples from different depths of the same profile have then been incorporated in the calculation of the average.

The standard error of the mean of the results for each type has been calculated in the usual way, on the assumption that each is a random sample of a uniform population.

Great difficulty was found in distinguishing with certainty between the quartz and the labradorite present in these soils. The refractive indices of the two are almost identical, and the felspar often appears quite clear, untwinned and with no trace of cleavage. Methods of staining were tried for the separation of these minerals, but hydrofluoric acid was necessary to attack the felspar, and no concentration could be found at which all the felspar was attacked and all the quartz left untouched. When doubtful cases arose, therefore, the axial figure was determined in order to identify the mineral. It was found quicker to determine the quartz-felspar ratio by a separate count of 100 grains, in which the axial figures were determined when necessary.

#### A. DESCRIPTION OF MINERALS.

##### Type 1 (Stony Risc Brown Loam).

The gravel of these soils consists of greatly decomposed basalt fragments, with a few grains of quartz and buckshot.

##### *Coarse Sand—*

Quartz (61 per cent.).—Generally sub-angular, sometimes rounded. Iron-stained along cracks and in hollows. Inclusions common; iron oxide, rutile needles, apatite, zircon, tourmaline and fluid inclusions have been noted, the last often arranged in bands in the manner characteristic of reef quartz.

Basalt (39 per cent.).—Fragments of crystalline basalt, highly decomposed.

Augite (trace).—Irregular broken fragments, with "titanium violet" tinge. Appear to be quite undecomposed.

Buckshot (trace).—Rounded and polished ironstone pellets.

*Fine Sand—*

Quartz.—As in coarse sand.

Plagioclase.—Irregular fragments, quite undecomposed. Refractive index about 1.565, indicating labradorite.

Augite.—As in coarse sand.

Iron Oxide.—Magnetite or ilmenite. Irregular grains and fine needles, usually fresh.

Basalt.—As in coarse sand.

Olivine.—Irregular fragments, characteristic olivine green with deep red-brown iddingsite border. Quite fresh.

Zircon.—Rounded grains or crystals with rounded terminations.

Tourmaline.—Rounded grains and short, stumpy prisms with rounded edges. Blue and brown.

Hyalite.—Water-clear, irregular fragments.

Broken fragments of the spicules of *Spongilla* are also present.

Type 2 (Stony Rise Clay).

The gravel and coarse sand of these soils contain only quartz and buckshot. The fine sand minerals are similar to those of Type 1, but the rock fragments, augite, and plagioclase grains are much smaller and show more alteration. Small rounded grains of leucoxene are also present.

Type 3 (Thistle Zone Soils).

Usually, the gravel and coarse sand of these soils contain only quartz and buckshot, but small fragments of decomposed basalt occur occasionally. The fine sand contains the same minerals as Type 1, but the augite and plagioclase show signs of alteration. Rutile, epidote, andalusite, and leucoxene have been observed in soils of this type.

Types 4-7 (Low Slope and Swamp Soils).

The gravel and coarse sand fractions of these soils consist of quartz grains with a varying amount of buckshot. Electro-magnetic separation shows that an average of 2 per cent. of the coarse sand of the low slope soils is buckshot, but the percentage in different samples varies considerably and in some cases reaches 7. The fine sand contains the same minerals as Type 1, with the exception that augite occurs only in samples taken in close proximity to basalt, as when a basalt boulder (or "floater") was encountered during sampling (e.g., Table XXI., Horizons c, d, e), or when the horizon sampled rested on basalt bedrock. In such cases, the plagioclase grains are fairly large and fresh, but normally the plagioclase of these soil types consists of extremely small and somewhat rounded grains, much decomposed and sometimes almost completely converted to secondary material. Rutile, epidote, andalusite and sillimanite occur occasionally in these soils, and small rounded grains of leucoxene are also present.

## Type 9 (Mountain Soils).

The gravel of these soils contains greatly decomposed fragments of scoria, and of vesicular basaltic glass, with a few rounded quartz grains. In the locality mentioned on page 82, large pebbles of quartz and sedimentary rock occur. Grains of buckshot also occur, but are very rare.

The coarse sand contains quartz (63 per cent.), scoria and basaltic glass (34 per cent.), olivine (3 per cent.), and a trace of augite and buckshot. Augite was observed only from samples taken near types of basalt, or on the central basalt plug. The olivine occurs mainly as perfectly formed crystals up to 5 mm. diameter. These have a transparent red-brown appearance, but broken edges show the characteristic olivine green with a red-brown iddingsite border.

The minerals of the fine sand are like those of Type 1, except that instead of fragments of crystalline basalt, splinters of basaltic glass occur. These are irregular in shape, the conchoidal fracture giving exceedingly sharp edges. The glass is light yellow to deep brown in colour, often containing bubbles, usually quite isotropic but with some fragments showing signs of devitrification. A few specimens show needles of iron oxide and feldspars already crystallized. The plagioclase of these soils is usually in the form of irregular fragments, but flat rhomb-shaped crystals occur which show very little cleavage, and in which the twinning is visible only when the crystal is turned on edge. The refractive index of these crystals is the same as that of the irregular grains.

## B. ORIGIN OF THE MINERALS.

The most striking feature of the minerals in the sand fractions is the abundance of non-basaltic material, chiefly quartz. This quartz, which is characterized by inclusions such as rutile and zircon, and which appears rounded and water-worn, could not have crystallized from the basaltic magma, and the grains of zircon, tourmaline, andalusite, &c., which are associated with the quartz, obviously represent foreign material. The most likely source of this material is the volcanic ash, since, as has been stated, the explosive rocks of Mt. Gellibrand contain considerable percentages of included quartz and other non-basaltic minerals, and the proportion of these foreign minerals was probably higher in the fine material which fell over the plains. The importance of this explosive material is indicated by a comparison of the sand percentages of soils from the Mt. Gellibrand area with those of basalt soils from other parts of the western plains (such as Woorndoo, below), taken several miles from the nearest volcanic cone. For example:—

	Coarse Sand.		Fine Sand.	
	..	%	..	%
014a (Mooleric Station)	..	23	..	40
Basalt soil from Woorndoo	..	2	..	22



The large fragments of olivine which occur in Types 4 to 7 probably came from the ash, since the explosive rocks of the mount show high percentages of large olivine crystals, and the occurrence of olivine in the soils of the plains is not connected with proximity to a stony rise.

It has been suggested elsewhere (Nicholls, 1936) that foreign material is commonly added to soils by the wind, and this is undoubtedly the case with much of the fine sand in the Mt. Gellibrand area. The non-basaltic minerals derived from ash and aeolian material would be expected to be similar, since they must be stable detrital minerals. Sponge spicules, however, have not been observed in the tuff, and therefore indicate the influence of wind transport. The coarser material is unlikely to have been transported long distances by the wind, and the sand percentages quoted above show that the addition of aeolian material cannot be responsible for all the non-basaltic minerals in the Mt. Gellibrand soils.

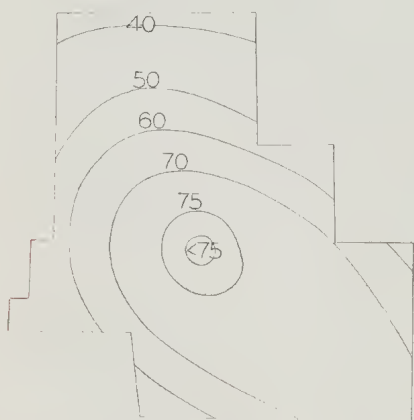


Fig. 7. Lines of equal percentages of total sand in top six inches.

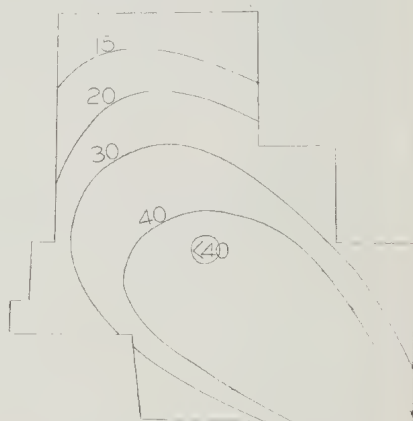


Fig. 8. Lines of equal percentages of coarse sand in top six inches.

The relation of the sand percentages of the soil to the volcano is shown by Figs. 7 and 8, which give respectively the total sand and coarse sand of the top six inches of soils from the low slope type. The lines of equal sand content form elliptical bands surrounding the mount, and the shape of the bands, like the shape of the contours of the mountain, shows that the prevailing winds during the period of eruption were from the north and north-west. The very sandy nature of the extreme south-east of the area is striking. The figures for coarse sand show greater regularity than those for total sand, possibly because of the inclusion in the latter of wind-blown material the distribution of which is not related to the mountain. The mineral composition of these sands is similar, but the percentage of total sand



in the soil varies from 32 in the north to 75 in the south and south-east, while the corresponding variation in the coarse sand is from 7 to 41.

It seems clear that the basalt was covered by showers of ash, possibly in the form of mud, and that the lower-lying parts received additional ash washed off the stony rises. One might expect to find a point in the profile where the percentage of quartz sand suddenly fell on passing from the weathered ash to the weathered basalt. In general, however, no such sharp line has been found, so that it is impossible to estimate with certainty the depth of the original ash layer. The typical "crab-hole" profile, 270, however, provides a possible example of such a definite change; the sand percentages at a depth of 10 feet (coarse sand 1 per cent., fine sand 10 per cent.) are of the same order as are found elsewhere in deep subsoils developed over basalt without any complications from volcanic ash. The occurrence of non-basaltic minerals in such subsoils has been mentioned in a previous paper (Nicholls, 1936), and it is suggested that this is due to the washing of sand down cracks formed during the dry season.

Some profiles show remarkable changes in the sandiness with depth. For example, the percentage of coarse sand in profile 161 passes from a maximum of 26 at the surface to a minimum of 14 at 2 feet, and rises again to a second maximum of 23 at 3 feet, below which it falls again. Since at any point in the area the falls of ash must have varied in composition, and must have been accompanied by changes in the direction and force of the wind, one would expect some irregularity in the sandiness of the various horizons; this may well be the cause of the second maximum just quoted.

Apart from this banding, there is usually a marked decrease in percentage of sand, on passing from surface to sub-surface—invariably so in the lighter soils. There are various causes for this. The process of leaching under somewhat acidic conditions involves some washing down of clay. At the same time, the accumulation of wind-blown sand enriches the surface in the finer sandy material. An important process on the slopes consists of the loss of the finer fractions with the run-off water, a process called "exluviation" by Marbut. A good example of this exluviation may be seen in the development of the crab-hole complex in the south-west of the surveyed area (see Section VI.).

The basaltic minerals are prominent only in soils which are immature owing to the influence of topography, as would be expected since all the basaltic minerals with the exception of iron oxide belong to unstable mineral species. The mountain soils show crystals of olivine and splinters of basaltic glass, but augite and felspar are not prominent, as the lava in the explosive

rocks seldom crystallized sufficiently to give large crystals of these. The brown loams on the steeper stony rises show high percentages of augite, labradorite and olivine, and grains and needles of iron oxide. These minerals are often large and irregular, and appear unweathered. On the broader type of stony rise, the decomposition of the basaltic minerals has proceeded much further.

The thistle zone soils show a small percentage of augite and comparatively fresh labradorite, apparently due to washing of these grains down from the stony rise. These minerals are usually small grains, and show definite signs of decomposition. Further down the slopes the influence of the rocks of the rise is not apparent, and the minerals appear to have been derived from the tuff and the underlying basalt sheets. Apart from the high content of quartz, and occasional large olivine grains, derived from the ash, the minerals resemble those of the mature basaltic soils from the extensive plains further west. Basalt is indicated only by small and much decomposed grains of plagioclase, and by the small grains of stable iron oxide.

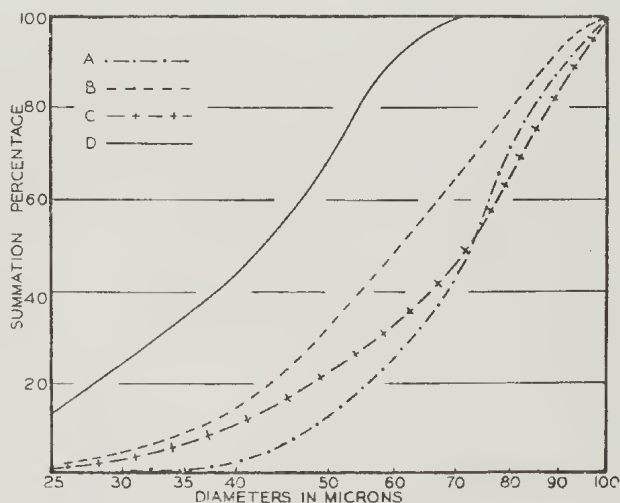


Fig. 9. Summation Curves, illustrating percentage composition by weight of fractions of various sizes in fine sand samples:—(A) Quartz in Tuff; (B) Quartz in sample 412a, directly above Tuff; (C) Quartz in several mature soils on the plains; (D) Iron Oxide in mature soils on plains.

The size distributions of certain minerals in the fine sands have been plotted in Fig. 9. Since the error in counting the few grains between 0.1 and 0.2 mm. in a sample of 500 is

unduly large, the curves cover only the distribution between 0.1 and 0.025 mm. The original figures were the number of grains of 20, 25, 30 . . . 100 microns in a sample or mixture of samples of at least 200 grains. These figures were twice smoothed by the process of adding successive pairs, and the resulting figure for each grain size was multiplied by the cube of its diameter so as to give the proportion of each size by weight. The final figures were then plotted logarithmically as summation curves. Three of the curves represent the distribution of quartz (*a*) in the tuff, (*b*) in the soil formed directly over this tuff on the mountain, and (*c*) from a mean of several mature soils on the plain. These curves illustrate the absence of the finest material from the quartz in the tuff, and the presence of this material in the soils is evidence that it has been added by the wind.

The fourth curve (*d*) shows that iron oxide occurs only below 0.08 mm. diameter, as would be expected since the crystals in the basalt and the tuff are all small. The curve suggests that the iron oxide may show a maximum in the silt fraction.

#### CORRELATION BETWEEN MINERALS AND FERTILITY.

The soils on the rises and on the mountain (types 1, 2, and 9) are much more fertile than the soils of the low slopes and swamps. This is seen by the quality of the flora, and by the much greater quantity of organic matter in the former types. While the amount of phosphorus extractable with hydrochloric acid is also usually much higher in the former types, the correlation of fertility with the minerals of the fine sand is very striking. The soils on the rises and on the mountain are immature, and contain large amounts of easily decomposable primary minerals in their sand fractions, namely labradorite and augite in the former case, and labradorite and basaltic glass in the latter. The soils on the slopes and swamps are relatively mature and devoid of useful minerals in their sand fractions.

The surface of the minerals in the fine sand is much smaller than the surface exposed in the silt, and the mineral composition of the silt is therefore more important for plant fertility. The presence of a mineral in the fine sand fraction may, however, be taken as evidence that it exists also in the silt fraction.

Among types 3-8, differences in fertility are due either to physical causes—such as differences in drainage or in texture—or to differences in the degree of saturation with bases; the better lime status of the thistle zone soils and the crabhole puffs is important in raising their fertility. The soils of the thistle zones, however, also have a better supply of basaltic minerals which are continually replenished by the washing of very fine particles from the rocks of the rises.

### VIII. Vegetation of the Area.

#### A. GENERAL DISCUSSION.

During the progress of the soil survey, many observations were taken of the present flora of the area. Lists of species present in various localities were drawn up and numerous specimens collected. The results of these observations have been compared, and the owners of the properties have been consulted with reference to the treatments which have been given to various parts of the areas. These observations have made it practicable to draw up a generalized picture of the vegetation as a whole, in the light of the treatment it has received. No survey of the existing communities would be of value without a preliminary discussion of the ways in which they are modified by man, either by his control of the animal population living on the vegetation, or through his modification of the soils by drainage, or the addition of phosphatic manures, or by the introduction of new plants which may be of value to the economic exploitation of the area.

From early photographs, and according to local tradition and records, the plains were originally largely covered by a herbaceous vegetation, much of which was coarse in character. Small trees (apparently chiefly Blackwood (*Acacia melanoxylon*) and Lightwood (*Acacia implexa*)) and bushes were common on the rises and it seems likely that larger trees may have been frequent on the slopes of Mt. Gellibrand. Fires followed by grazing removed these woody perennials quickly, and to-day very few remain. During recent years the lack of shelter has been remedied by the introduction of numerous plantations in various parts, whilst a large number of trees have been planted around the houses. Apart from these, the only shrubs or trees are one or two individual specimens of *Acacia armata* and *Solanum aviculare*, but the remains of an arboreal species of *Banksia* were encountered in two places. With these exceptions, the entire vegetation to-day is herbaceous in nature.

The effect of the grazing animal on the herbaceous vegetation is extremely marked, and by no means uniform on the various soil types.

The properties have been used for carrying sheep for the most part, although a certain number of cattle are always kept, probably with the idea of dealing with the rougher grazing material such as the tussocks of *Poa caespitosa* which are very frequent in many sections. The sheep are very selective in their activities, showing a marked preference for the short, "sweet" herbage of the stony rises; naturally therefore they tend to camp on these regions which accordingly receive some extra amounts of organic manure from their droppings. They graze the vegetation of the low slopes quite freely, but pay very little attention to the *Poa caespitosa* tussocks. During the

periods of the year when the amount of feed is relatively sparse they turn to the less nutritious, dry material, but, during the occupancy of the present owners, it has never been the policy to stock the areas to such an extent as to force the sheep to graze *Poa caespitosa* extensively.

Experience has shown that, in all the better-drained sections of the area, profound changes can be brought about in the balance of vegetation by the application of superphosphate as a top-dressing. This procedure has been adopted on a more or less modest scale over parts of the area. As a result, the proportion of clovers in the vegetation has risen markedly, and in general the grasses have also been directly or indirectly stimulated to an increased growth. Where the distribution has been carried out by means of a seed drill, the change in the herbage is sufficient to show up very clearly in the aeroplane photographs of certain paddocks. The top-dressing procedure has been most intensive on the slopes of the mount adjacent to the southern station where perennial rye grass was introduced many years ago and has been cultivated for both the production of seed, and the grazing of dairy cows. Other paddocks which have been top-dressed have been treated from time to time, but on these the progress has never been stimulated to such an extent as to oust the *Danthonias* and other native species from their dominant position in the better-drained parts. In paddocks on the low-slope types of soil where no top-dressing has been given, vegetation is partly open in character, bare spaces between the individual plants being frequent. It seems reasonable to suppose that this type of vegetation is the natural pasturage to which 80 or more years of grazing have reduced the original vegetation. The result of the addition of superphosphate is to diminish the amount of open space, both by increasing the vigour of the individual *Danthonias* and also by making the conditions more suitable for clovers and other annual species to develop on the bare spaces between the individual *Danthonia* plants.

In the parts of the area which are subject to flooding in winter, the vegetation takes a new form; tussocks of *Poa caespitosa* become increasingly frequent and many of the pans and swamps are relatively unproductive from the grazing point of view. Here a sustained effort has been made to improve the carrying capacity of the country by altering the conditions in various ways which lead to improved drainage and the development of more satisfactory plant communities. Several distinct methods of approaching the problem have been adopted. In the case of the larger swamps, shallow drains have been ploughed along the contours so as to collect the water as it runs off from the rises towards the lower levels (see Plate V., lower photograph), and in addition, drains have sometimes been made through the centre of the swamps (see Plate V, upper photograph). The marginal method is practised on the southern half of the area where the swamps are large,



and of heavy clays which are somewhat acidic. The central drain method has been used largely on the northern half, and seems well suited to the crabholey type of clay which is self-mulching, and can absorb a considerable amount of water down the cracks before becoming water-logged. On some swamps it has been found necessary to adopt both methods. On "pan and bank" country, the method employed is to plough or dig through the banks wherever the water tends to flow over the bank from one pan to another during periods of heavy rain. The combined result of all these efforts has been to decrease the areas of badly-drained soil, and consequently to reduce the amount of land covered by the vegetation typical of such areas. Much of the drainage work is recent in date, and as the change in the vegetation takes place only slowly unless cultivation is actually invoked many of the wetter areas are in a transitional stage.

Some of the larger swamps have actually been drained and used for cultivation of oats, wheat, or grazing crops from time to time. This process has been largely confined to the northern half of the area where the crabholey type of soil has proved itself of value for this purpose. A certain number of weeds have been introduced as a direct consequence of these cultivations.

In view of these numerous ways in which man has influenced the herbaceous vegetation, it has not seemed advisable to do more than separate the plant communities into two types—one found on the situations which are badly drained, and the other on the better-drained regions. The areas occupied by each type show a fairly wide range of variations according to the intensity with which the various factors have been allowed to act upon them; and it is of some interest to indicate the way in which the frequencies of the various species increase or decrease according to differences in soil or in treatment.

#### B. AREAS NOT LIABLE TO SWAMPING.

Table XXII. gives a list of the plants which were observed in localities which are included in this category. The symbols in the various columns indicate the relative frequency of each species; wherever a symbol is enclosed in a bracket it is intended to indicate that the intensity of occurrence is somewhat localized. In the case of certain plants (particularly annuals) this localization is probably a direct result of different grazing treatments on different paddocks. For instance, if there were a palatable species of annual plant fairly uniformly distributed over the drained areas of several paddocks, and, during its period of flowering and seed production, some of the paddocks were grazed more intensively than others, then there would be a tendency for this species to be relatively scarce in the following season; conversely, lack of grazing during this critical period would increase the probability that the species would appear in abundance in the next year.



The floristic record for the mountain soil (Type 9) was derived from the paddocks on the top and upper parts of Mount Gellibrand where the land is used for grazing only. Paddocks on the middle or lower slopes on the south and eastern sides were not studied, as the practice of cutting grass hay, or taking crops of seed of Perennial Rye Grass has introduced divergences in the vegetation which would merely obscure the general issue. The soils of this type have been shown to be high both in phosphate and in primary minerals (see Tables X. and XX.). Their surface layers have a relatively satisfactory texture

TABLE XXII.—LISTS OF PLANTS ON SOIL TYPES CHARACTERISTIC OF DRIER PARTS OF THE AREA.

			Mountain Soil.	Stony Rise Brown Loam	Thistle Zone	Low Slope.
<i>Cheilanthes tenuifolius</i>	..	..	..	r.	..	..
<i>Themeda triandra</i>	..	..	..	..	..	(ab.)
<i>Koeleria phleoides</i>	..	..	..	..	..	r.
<i>Festuca bromoides</i>	..	..	ab.	f.	..	(f)
<i>Festuca rigida</i>	..	..	(f)	..	occ.	occ.
<i>Bromus mollis</i>	..	..	d.	d.	ab.	occ.
<i>Briza minor</i>	..	..	..	(ab.)	f.	f.
<i>Poa caespitosa</i>	..	..	occ.	..	..	small form occ.
<i>Calamagrostis quadrisetia</i>	..	..	..	..	..	(occ.)
<i>Calamagrostis filiformis</i>	..	..	..	..	..	(ab.)
<i>Dichelachne crinita</i>	..	..	..	..	..	f.
<i>Pentapogon quadrifidus</i>	..	..	..	..	..	(occ.)
<i>Stipa variabilis</i>	..	..	occ.	f.	..	f.
<i>Aira caryophyllea</i>	..	..	(f)	ab.	f.	ab.
<i>Danthonia geniculata</i>	..	..	..	ab.	f.	ab.
<i>Danthonia semianularis</i>	..	..	ab.	ab.	f.	ab.
<i>Lolium perenne</i>	..	..	ab.	..	..	(f)
<i>Agropyrum scabrum</i>	..	..	(f)	(f)	..	occ.
<i>Hordeum marinum</i>	..	..	(f)	..	..	..
<i>Hordeum maritimum</i>	..	..	f.	..	f.	(occ.)
<i>Juncus bufonius</i>	..	..	..	occ.	..	occ.
<i>Juncus capitatus</i>	..	..	..	occ.	..	r.
<i>Lomandra glauca</i>	..	..	..	..	..	(occ.)
<i>Bulbine bulbosa</i>	..	..	..	..	..	occ.
<i>Dichopogon strictus</i>	..	..	..	..	..	(occ.)
<i>Arthropodium paniculatum</i>	..	..	..	..	..	(occ.)
<i>Romulea bulbocodium</i>	..	..	..	..	..	(f)
<i>Rumex dumosus</i>	..	..	occ.	occ.	occ.	..
<i>Rumex acetosella</i>	..	..	..	occ.	..	occ.
<i>Rhagodia nutans</i>	..	..	..	..	..	(occ.)
<i>Trichinum spathulatum</i>	..	..	occ.	occ.	f.	occ.
<i>Trichinum muerocephalum</i>	..	..	..	occ.	..	..
<i>Stellaria pungens</i>	..	..	..	..	..	(occ.)
<i>Cernitium glomeratum</i>	..	..	..	f.	..	..
<i>Moruehia erecta</i>	..	..	occ.	f.	..	..
<i>Sagina apetala</i>	..	..	..	f.	..	occ.
<i>Polycarpon tetraphyllum</i>	..	..	..	occ.	..	f.
<i>Silene gallica</i>	..	..	..	f.	..	occ.
<i>Ranunculus arvensis</i>	..	..	..	..	..	(f)
<i>Drosera peltata</i>	..	..	..	..	..	(occ.)
<i>Crassula Sieberiana</i>	..	..	..	ab.	..	(f)
<i>Crassula macrantha</i>	..	..	..	(ab.)	..	(f)
<i>Acuena ovina</i>	..	..	..	..	..	(occ.)
<i>Acuena sanguisorba</i>	..	..	..	..	..	(occ.)
<i>Trifolium procumbens</i>	..	..	(ab.)	ab.	ab.	f.
<i>Trifolium minus</i>	..	..	f.	f.	ab.	(f)
<i>Trifolium tomentosum</i>	..	..	occ.	(ab.)	f.	(occ.)
<i>Trifolium cernuum</i>	..	..	..	(f)	occ.	(occ.)
<i>Trifolium glomeratum</i>	..	..	(f)	occ.	f.	(occ.)
<i>Trifolium subterraneum</i>	..	..	f.	(f)	occ.	(f)
<i>Trifolium striatum</i>	..	..	..	r.	..	..
<i>Trifolium angustifolium</i>	..	..	..	..	..	r.
<i>Medicago arabica</i>	..	..	occ.	occ.	..	..
<i>Medicago hispida</i>	..	..	occ.	..	..	..

TABLE XXII—continued.

	Mountain Soil.	Stony Rise Brown Loam.	Thistle Zone.	Low Slope.
<i>Suaeda behriana</i> .. ..	..	r.	..	..
<i>Kennedy prostrata</i> .. ..	..	r.	..	..
<i>Geranium pilosum</i> .. ..	..	..	..	occ.
<i>Erodium cicutarium</i> .. ..	f.	(ab.)	occ.	..
<i>Erodium cyparissium</i> .. ..	..	occ.	..	f.
<i>Oxalis corniculata</i> .. ..	f.	ab.	ab.	f.
<i>Linum marginale</i> .. ..	..	..	..	(occ.)
<i>Bredemeyera ericinum</i> .. ..	..	occ.	..	occ.
<i>Paranthera microphylla</i> .. ..	..	occ.	..	(f)
<i>Hypericum japonicum</i> .. ..	..	..	..	(occ.)
<i>Pimelea curciflora</i> .. ..	..	..	..	(f)
<i>Hydrocotyle callicarpa</i> .. ..	..	..	..	(occ.)
<i>Hydrocotyle lasiflora</i> .. ..	..	..	..	r.
<i>Eryngium rostratum</i> .. ..	..	occ.	r.	ab.
<i>Daucus gluchiliatus</i> .. ..	..	(ab.)	f.	(ab.)
<i>Anagallis orreensis</i> .. ..	..	..	..	occ.
<i>Sedum ovale</i> .. ..	..	occ.	..	(f)
<i>Cuscuta epilinum</i> .. ..	..	..	..	(ab.)
<i>Dichondra repens</i> .. ..	(ab.)	(ab.)	occ.	(f)
<i>Convolvulus erubescens</i> .. ..	..	occ.	occ.	(f)
<i>Mitrasotis australis</i> .. ..	occ.	..	..	occ.
<i>Marrubium vulgare</i> .. ..	(f)	..	..	..
<i>Solanum aviculare</i> .. ..	..	r.	..	..
<i>Ferocaria gracilis</i> .. ..	..	occ.	..	occ.
<i>Bartschia latifolia</i> .. ..	..	occ.	occ.	(occ.)
<i>Plantago coronopus</i> .. ..	..	(f)	..	(occ.)
<i>Plantago varia</i> .. ..	occ.	(ab.)	ab.	(f)
<i>Galium murale</i> .. ..	occ.	occ.	..	occ.
<i>Asperula caespita</i> .. ..	(f)	occ.	f.	occ.
<i>Sheardia argensis</i> .. ..	occ.	..	..	(f)
<i>Wahlenbergia gracilis</i> .. ..	occ.	occ.	..	f.
<i>Lobelia protoides</i> .. ..	..	..	..	(ab.)
<i>Vellaria parviflora</i> .. ..	..	..	..	(occ.)
<i>Goodenia pinnatifida</i> .. ..	..	..	..	(occ.)
<i>Brachycome exilis</i> .. ..	..	..	..	f.
<i>Brachycome decipiens</i> .. ..	..	..	(occ.)	..
<i>Calotis scabiosaefolia</i> .. ..	..	..	..	(f)
<i>Gnaphalium purpureum</i> .. ..	..	..	..	occ.
<i>Gnaphalium japonicum</i> .. ..	..	..	..	(f)
<i>Heliopsis australe</i> .. ..	..	(ab.)	..	(ab.)
<i>Helichrysum apiculatum</i> .. ..	..	ab.	..	f.
<i>Helichrysum scorpioides</i> .. ..	..	..	..	occ.
<i>Leptorhynchus squamatus</i> .. ..	..	occ.	occ.	ab.
<i>Podolepis acuminata</i> .. ..	..	..	..	(occ.)
<i>Myriocephalus rhizocephalus</i> .. ..	..	..	..	occ.
<i>Calceophylus citreus</i> .. ..	..	..	..	(occ.)
<i>Craspedia uniflora</i> .. ..	..	..	..	(occ.)
<i>Craspedia chrysantha</i> .. ..	..	..	..	(occ.)
<i>Cobula coronopifolia</i> .. ..	..	..	..	f.
<i>Soliva sessilis</i> .. ..	..	..	..	r.
<i>Cryptostemma calendulaceum</i> .. ..	(f)	f.	ab.	..
<i>Cymbonotus Laysonianus</i> .. ..	..	..	occ.	(occ.)
<i>Carduus Marianus</i> .. ..	occ.	occ.	..	..
<i>Carduus pycnocephalus</i> .. ..	(ab.)	(ab.)	ab.	..
<i>Centaurea melitensis</i> .. ..	..	..	..	occ.
<i>Microseris scopigera</i> .. ..	..	..	..	(occ.)
<i>Hedyscyma cretica</i> .. ..	..	..	f.	occ.
<i>Hypochaeris radicata</i> .. ..	occ.	occ.	f.	(occ.)
<i>Senecio albaerens</i> .. ..	f.	(f)	occ.	..
<i>Senecio asper</i> .. ..	occ.	(occ.)	..	..

ab.—Abundant. (ab.)—Locally abundant. f.—Frequent. (f) Locally frequent. d.—Dominant. occ.—Occasional. (occ.)—Locally occasional. r.—Rare.

and the subsoils allow water to percolate downwards. As a result they are eminently suitable for growth of pasture herbage. Their vegetation is therefore a close one, and contains species which are indicative of high fertility such as *Lolium perenne*, *Carduus Marianus* and species of *Trifolium* in abundance.

The general vegetation of the stony rise brown loams (Type 1) is somewhat similar in nature, but as already noted, the grazing on these areas is particularly severe owing to the habits of the sheep which incidentally are also partly responsible for maintaining the level of fertility in the soil (see Section V., B.).

Both on the mountain and on the stony rises there are many patches where the presence of boulders leads to soil development of merely 1 or 2 inches. In such locations the plants are subjected to conditions of severe desiccation whenever rain is deficient for more than a few days, and atmospheric humidity is low. The species occurring in such situations are, first and foremost, the lichens and mosses which have not been identified, and then certain small annuals such as the two *Crassulas* (*C. Sieberiana* and *C. macrantha*), *Aira caryophylla*, *Sagina apetala*. Here and there between boulders are deep crevices which have not been entirely filled with soil; in one such *Cheilanthes tenuifolius* was found.

Naturally there are areas showing every gradation in respect to soil depth, and consequently there are similar gradations in the vegetation from these communities of annuals to those which may be regarded as characteristic of the deeper brown loams. The species of the stony rise tops vary considerably according to the breadth of the rise; the list shown has been put together as typical of a rise on which there were numerous boulders and little indication that water was retained sufficiently to give rise to semi-swamp conditions.

The zone of black soils around the rises has already been described. Its deep, friable, self-mulching soil makes it an effective zone for growth, but the cracking which takes place in summer probably lowers the water content of the upper layers, and may result in physical damage to the shallower roots. This favours the deep rooted type of perennial or biennial, notably *Carduus pycnocephalus*, and the vigorous annual which is able to establish itself effectively and grow rapidly when the season breaks in the autumn. Small annuals and perennials with spreading root systems, e.g., *Danthonias*, are less frequent.

The low slope type of soil is occupied by such herbaceous perennials as are able to withstand the desiccation of the dry winds of summer, or by annuals, where such can effect establishment and produce seed readily. The perennial native grass species with relatively narrow and moderately xerophilous leaves are frequent, as are Composites with hirsute, light-reflecting leaves. On areas where no superphosphate has been added the perennial plants are relatively small, and are separated by several inches from one another. The intervening spaces are more or less colonized by small annuals among which clovers are relatively inconspicuous. Where the paddocks have been top-dressed, the individual plants of grasses are generally larger

and closer together, while the clovers (especially *Trifolium procumbens* and *T. minus*) are the most important annual species.

In certain paddocks without phosphate treatment, *Eryngium rostratum* has come to occupy an important position. According to local tradition this is largely due to overgrazing in a year when this species seeded very freely. Where more vigorous growth has been stimulated among the herbage this plant although frequent is less abundant.

*Cuscuta epilimum* occurs on a wide range of host plants in some arcas. It was not noticed on the vegetation of the "improved" paddocks, but this may be no more than a chance effect.

*Lolium perenne* is entirely absent from low-slope areas which have not been treated with superphosphate, but in the treated areas of the southern property the species is more prevalent, partly because at times a certain amount of seed has been distributed with the manure and partly because the level of soil fertility approaches that requisite for the progress of the species.

#### C. THE CRABHOLE COMPLEX.

As already described, these areas have two distinct soils, differing in elevation and in physical texture. The puffs of dark self-mulching soil are similar in nature to the thistle zones of the stony rises. Their flora is also very similar, deep-rooted perennials or biennials, such as *Carduus pycnocephalus*, *Danthonia semiannularis*, and *Poa caespitosa* being mixed with vigorous annual grasses and clovers such as *Hordeum maritimum*, *Bromus mollis*, *Trifolium procumbens*, and *Medicago hispida*. There are, however, numerous blank areas between the plants. The "crabholes" themselves support a denser vegetation which is apparently less heavily grazed by the stock. The following is a list of some of the plants more frequently found on these depressions:—

<i>Poa caespitosa</i>	<i>Trifolium minus</i>
<i>Danthonia semiannularis</i>	<i>Daucus glochidiatus</i>
<i>Bromus mollis</i>	<i>Asperula conferta</i>
<i>Leptorrhynchus squamatus</i>	<i>Wahlenbergia gracilis</i>
<i>Lepturus cylindricus</i>	<i>Helichrysum scorpioides</i> .

Most of the large areas of the crabhole type have been drained and ploughed, and either cultivated and used for cropping, or sown down to pastures with rye grasses, subterranean and other clovers.

#### D. THE MOISTER AREAS.

In wetter spots on the low slopes tussocks of *Poa caespitosa* increase in numbers, and in some regions juncaceous tussocks appear. Where "pan and bank" formations occur, the "pans"

usually have a more aquatic type of vegetation with *Poa caespitosa* tussocks, whilst the "banks" bear low slope vegetation usually with many tussocks.

Fig. 10 shows an actual transect taken along a line passing from a low slope into a pan of the type characteristic of the southern half of the area. *Lobelia pratioides* is a constant feature of the pan areas, but is rare on the banks. The ordinary annual species are often incapable of establishing themselves in the pans; presumably this is partly due to the amount of water in the winter and partly to the tenacious nature of the clay soils. Aquatic annuals are unsuccessful owing to the long dry period in the summer. Some of the pans retain their water much longer than others, and in these the aquatic species are able to establish and maintain themselves more effectively. There is some diversity between the species to be found in various pans, but the following list contains most of the commoner forms found in the wetter areas:—

<i>Potamogeton tricarlinatus</i>	<i>Juncus prismatocarpus</i>
<i>Glyceria fluitans</i>	<i>Juncus holoschoenus</i>
<i>Amphibromus nervosus</i>	<i>Juncus pauciflorus</i>
<i>Lepturus cylindricus</i>	<i>Juncus vaginatus</i>
<i>Scirpus setaceus</i>	<i>Juncus polyanthemus</i>
<i>Heliocharis acuta</i>	<i>Juncus plebeius</i>
<i>Heliocharis acicularis</i>	<i>Claytonia australasica</i>
<i>Carex declinata</i>	<i>Ranunculus rivularis</i>
<i>Schoenus apogon</i>	<i>Ranunculus parviflorus</i>
<i>Juncella submersa</i>	<i>Myriophyllum propinquum</i>
<i>Aphelia gracilis</i>	<i>Utricularia dichotoma.</i>

Some of the species on the list (such as *Potamogeton tricarlinatus*, *Glyceria fluitans*, and *Myriophyllum propinquum*) are from areas in which water is artificially retained for stock purposes, others are from pans which are dry during part of the summer. As is usual in the vegetation of ponds with shelving banks the plants show a zonal arrangement round the margins. The drier land surrounding a typical wet clay swamp bears *Poa caespitosa* in large tussocks with some of the low-slope plants, among which appear *Lobelia pratioides*, *Ranunculus arvensis*, and *Juncus* spp., while *Trifolium cernuum* and *Lotus corniculatus* are occasionally present. The wetter side frequently has a marked belt of *Utricularia dichotoma*, and *Amphibromus nervosus*, *Heliocharis acuta* and *Heliocharis acicularis* are often abundant and extend for some distance on the deeper side. *Stellaria palustris* and *Ranunculus rivularis* appear at about this level in some pans, while in deeper water *Glyceria fluitans*, *Potamogeton carinatus*, and *Myriophyllum propinquum* occur in some cases.

As already noted, some of the large swamps have been drained by opening surface ditches; the resulting area has the heavy clay soil described as Type 6. This is not an easy substratum for



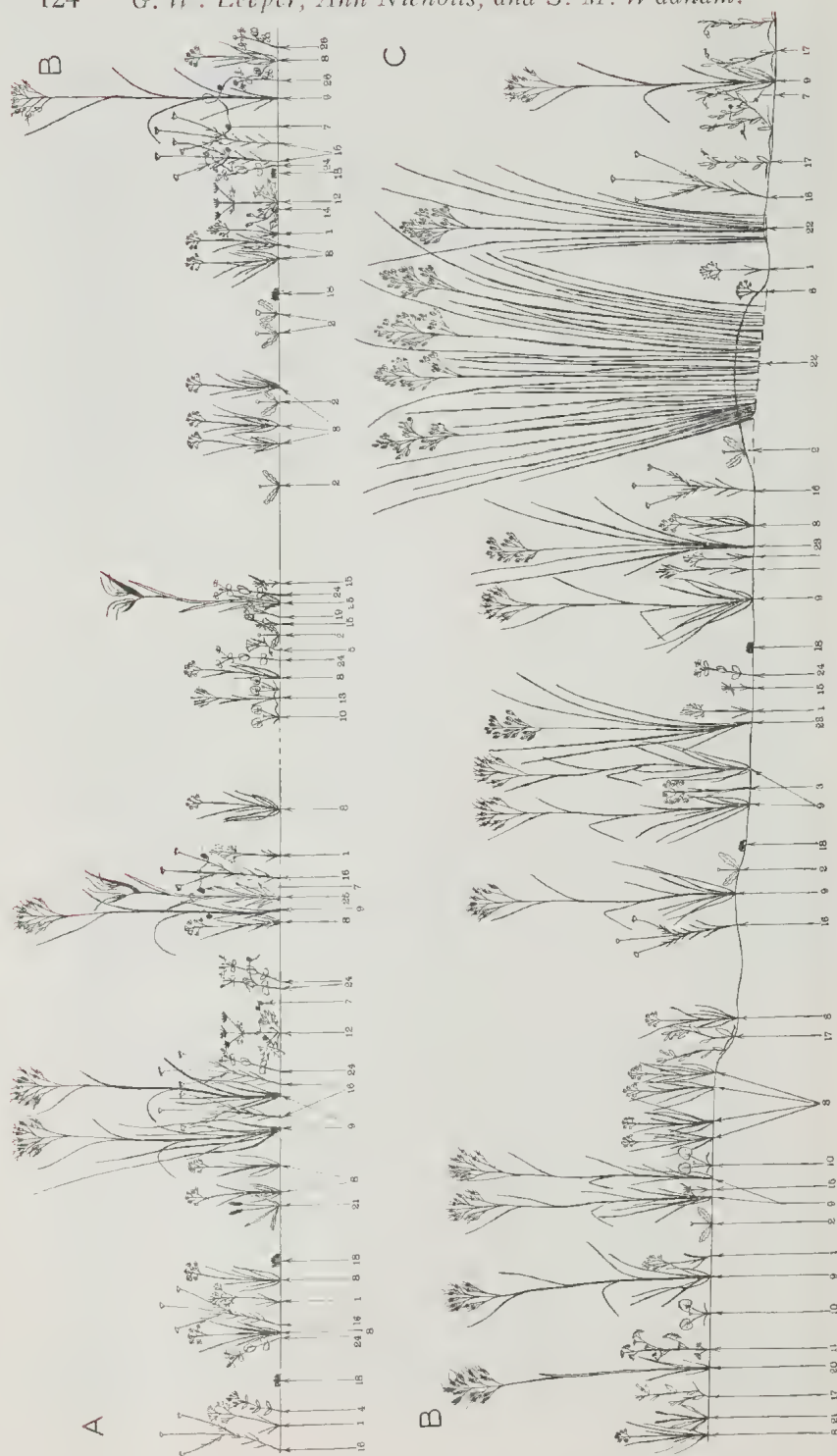


Fig. 10. Ten Metre Transect from Low Slope to Pan.

U.R.F. del.



plant growth, and the resultant vegetation is poor. Salinity, low base saturation and high clay content may contribute to this result. Some of these "reclaimed" clay swamps have been ploughed up, but the low humus content of the clay renders them difficult to work. On one such swamp, which was cultivated and sown with perennial rye grass and subterranean clover, a vigorous response was obtained following the addition of sheep droppings gathered from beneath a shearing shed.

## KEY TO FIG. 10.

<i>Aira caryophylla</i> ..	..	1	<i>Hypochaeris radicata</i> ..	..	14
<i>Brachycome decipiens</i> ..	..	2	<i>Juncus capitatus</i> ..	..	15
<i>Briza minor</i> ..	..	3	<i>Leptorrhynchus squamatus</i> ..	..	16
<i>Cerastium glomeratum</i> ..	..	4	<i>Lobelia pratioides</i> ..	..	17
<i>Convolvulus erubescens</i> ..	..	5	Moss ..	..	18
<i>Crassula macrantha</i> ..	..	6	<i>Oxalis corniculata</i> ..	..	19
<i>Cuscuta epithymum</i> ..	..	7	<i>Pentapogon quadrifidus</i> ..	..	20
<i>Danthonia geniculata</i> ..	..	8	<i>Plantago varia</i> ..	..	21
<i>D. semiannularis</i> ..	..	9	<i>Poa caespitosa</i> ..	..	22
<i>Dichondra repens</i> ..	..	10	<i>Poa caespitosa seedling</i> ..	..	23
<i>Drosera peltata</i> ..	..	11	<i>Sebaea ovata</i> ..	..	24
<i>Eryngium rostratum</i> ..	..	12	<i>Themeda triandra</i> ..	..	25
<i>Festuca bromoides</i> ..	..	13	<i>Trifolium procumbens</i> ..	..	26

## IX. Productive Use of the Land.

As it is commonly supposed that the Western District of Victoria is an extremely fertile area in respect to its soils, and also enjoys a very favorable climate, a brief critical survey of these factors from the standpoint of rural production in the area now under consideration is of some interest.

The climate is typical of the drier belt of the Western District which lies south of the Ballarat Plateau. The average monthly rainfall for the southern station, Mooleric, is given in Table XXIII. That for the northern station, Turkeith, is somewhat lower.

TABLE XXIII.—MONTHLY RAINFALL AT MOOLERIC (40-YEAR AVERAGE).

Month.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Total
Inches rain	1·06	1·24	1·74	1·68	2·09	2·34	2·17	2·39	2·50	2·18	1·80	1·54	22·73

The summers are warm and dry and evaporation is high. The occasional rains which fall are of tropical origin and erratic; (thus the standard deviation from the mean for January is just under an inch, while the same figure holds for July, which has over twice the rainfall). The winters are cool and wet, and rain

falls on the majority of days. Since surface soil temperatures remain too low for rapid growth during June, July, and August (the mean temperature being below 50° F.) the productivity of pastures during the succeeding spring depends very largely on an early break in the autumn. Good falls of rain in March and April allow perennials to make an early start and the annuals to establish themselves effectively before the surface soil temperature falls below 50° F., and there is then a rapid response to the higher temperatures in the following spring. The position is analogous to that studied in Adelaide by Trumble and Cornish (1936) who found that the production of pasture in any year was highly correlated with the rainfall in March and April. The "break" in the season at Mooleric—i.e., the date after which the ground remains moist enough for germination and growth—has varied during the period for which records are available between late January and late May.

The only soils which are inherently high in mineral fertility in our particular area, are the dark brown soils of the mountain (Type 9) and the tops of the rises (Types 1 and 2) and those of the thistle zone (Type 3). The rich mountain soils are confined to the top and upper slopes of the cone where cultivation is not easy. On these, intensive pasture production is practised on the southern and eastern slopes which are less subject to insolation and therefore more favorable for high-grade pasture species which are broader-leaved and less xerophytic than the native grasses. The brown loam of the rises and its attendant thistle zones would be worthy of cultivation, but the removal of a large number of boulders distributed on and in the former would be a Herculean task. Such a labour might be attempted by a rural community faced with either food shortage or land hunger, but it would be quite impracticable by one which must needs consider land utilization from an economic standpoint.

The crabholey soils (Types 7 and 8) have been developed into cultivable land wherever the existing areas extend over about 20 acres. They are fertile and capable of growing good cereal or hay crops, especially in seasons when winter rainfall over the area as a whole is not sufficiently heavy to cause serious flooding on these lower-lying patches.

The low-slope soils are in most cases free from boulders. Their inherent fertility is low in respect to both phosphorus and nitrogen; when the former deficiency is overcome by the use of superphosphate, and the latter by the secondary effect of the nodule bacteria on the roots of the legumes the resultant surface soil is satisfactory for pastures. The actual type of pasturage which it will be economical to stimulate on areas of this class is in some doubt. An average annual rainfall of 22 inches in Southern Victoria is on the border-line of the requirements of Perennial

Rye Grass. It seems quite clear that that species will not manage to maintain itself in these localities, unless the soil fertility is also maintained at a high level. In one or two of the low-slope paddocks Perennial Rye Grass seed has been scratched in without any previous attention to raising the fertility through the use of superphosphate and clovers. In general the results which have been achieved by this method have not been satisfactory. Exactly how far it would be necessary to raise the fertility before Perennial Rye Grass became permanently established, and the nature of the balance between the clovers and the rye grasses which would doubtless be necessary in order to ensure that degree of permanence are matters of speculation and considerable interest.

The main obstacle to intensive production on these low-slope areas is the impervious subsoil which hinders the downward percolation of water. Superficial drainage channels have been provided to some extent. Underground tile drains would be more effective, but too costly to be considered as a practical economic project. Even if this were not the case it would be necessary to consider their ultimate effects in the danger of causing the flooding of lands lower down in the same drainage system.

The wetness of these soils in the winter would make an agricultural system based on cultivation somewhat precarious, and it is probable that the most effective way of using the land is as pasturage, particularly if steps are taken to raise the productivity of the area by improving the types of plants which are grown. The extent to which this pasture improvement should be carried would depend upon the fertility problem which has already been stated above. It is, however, necessary to remember that improvement of pasturage will lead to a greater liability to stock diseases than is at present experienced. Disabilities of this type, however, can be overcome by the application of scientific knowledge in the management of the sheep. Some of the pastures are at present in large paddocks, some comprising 640 acres, and it is probable that subdivision which has been and is going on will lead to more effective utilization of the country. In this connexion, however, it must be remembered that water supplies are difficult during the summer months and usually entail the sinking of bores and the provision of tanks. The depth at which water can be struck below the basalt is very variable, and the costs have in many cases proved to be high.

The soils of the clay swamps are at least as difficult as those of the low slopes. Drainage is naturally the main problem, but even if this were satisfactorily solved the need for improving the physical features of the clays by increasing the amount of organic matter, or adding calcium compounds in the form of lime or gypsum, would still remain. The extent to which the relatively

high salinity of these soils is a serious factor is at present unknown.

It is of some interest to note the following extract from *Western Victoria, its Geography, Geology, and Social Condition*, a narrative of an educational tour in 1857 by James Bonwick, who, when discussing a station some 4 or 5 miles away from the area which we have described, states: "The soil is not good for agriculture. Much of it was regarded as too poor for pastoral purposes; but the feed has greatly improved of late years. Exposure to cold winds, unbroken by hills or hedges, renders cultivation upon the plains anything but profitable. The same exposure and a want of drainage are formidable impediments to the breeding of sheep, though they fatten well upon the pasture. The farmer, again, could do little upon the Western Plains, for not only the reasons above mentioned, but for the difficulty of conveying produce in winter over the spewy ground; and the great distance often from wood and water. Stations have occasionally to send 30 or even 40 miles for firewood, and suffer much from want of running water. . . . The plains are best suited to sheep. In consequence of absence of timber, notwithstanding a hungry clay soil, the grass is so close, though short, and of so nutritious a character that sheep rapidly fatten." Nowadays the problem of water supply has been solved and firewood is grown in plantations on the stations. Drainage, though it has improved, is still a main problem. The carrying capacity of the country has been doubtless greatly increased in those places where top-dressing has been practised, but the land is still to a very large extent pastoral.

## **X. Notes on the Map, with Interpretation of Aerial Photograph.**

It will be noticed that Types 4, 5, and 9 are the only types to be mapped simply as such; the other signs represent complexes. It was impossible on this scale to differentiate between the true stony-rise soils (Types 1 and 2) and the soils of the adjacent thistle zones (Type 3). These types have therefore been combined as "stony-rise complex." This procedure, although combining very different types of soil, has the merit of marking those areas which are too rocky for cultivation.

A different sign has been used for the pan-and-bank complex according as it occurs in swamps surrounded by slopes of soil Type 4 or those of Type 5, the banks being of light and heavy texture respectively in these two cases. Two further signs have been introduced to cover those areas which are transitional between the low-slope type and the respective pan-and-bank complex. These areas are easily picked out on the photograph



by their stippled appearance. The occasional areas of soil type 6, uninterrupted by banks, are marked by the conventional sign for swamp. Types 7 and 8 are combined in the sign for the crabhole complex.

Two typical portions of the aerial photograph are reproduced on a large scale in Plate V, and the corresponding portions of the soil map are given in Figs. 11 and 12. On this scale one can separate the stony-rise complex into its parts so as to show the extent of the thistle zones (see legend on the large map). Types 2 and 3, however, are still mapped together. Except for a patch of Type 2 in the upper part of the lower photograph, the soils mapped under the sign of thistle-zone are in fact of Type 3.

The upper photograph shows a series of stony rises, in which the rocks stand out by reason of their light colour. The thistle-zone is shown by the dark rim around the rocks; ridges connecting rises also consist of this type. Where the sides are relatively steep, as here, the thistle zone forms only a narrow rim to the rises on their transition to the low slopes. The pan-and-bank complex is also well shown, especially in the upper right-hand corner, where the pans are covered with water which shows white on the pans and on the road. Below this and to the left, drains have been cut through the swampy country and most of the pans show as dark patches, where drainage, though still poor, is better than before. The lowest-lying part of this swamp is an unusually large expanse (13 acres) of soil Type 6. It is interesting to note that the outlet from this swamp has had to be cut through a stony rise.

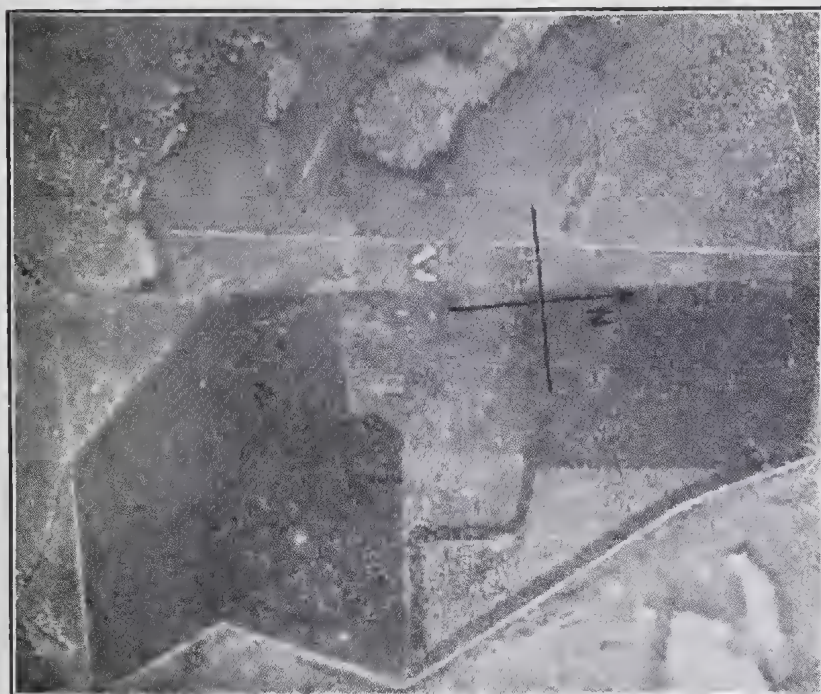
Other swampy areas may be seen on this photograph. In the upper left-hand corner the transition from the pan-and-bank complex to the low-slope type takes place through the intermediate form referred to above. One or two isolated swamps may also be seen at the foot of one rise. Other interesting features in this photograph are the cattle in the swamp and elsewhere, e.g., at 1 inch to the right of the point of the arrow, and sheep tracks in the lower left corner.

The lower photograph is taken 3 miles north of the mountain where heavy soil (Type 5) is developed on the slopes. In such areas the crabhole complex is often developed on the swamps; it is easily picked out on the photograph on which the puffs appear as an assemblage of light spots. The lower-lying parts also include areas of heavy soil which is intermediate between the low-slope type and the pan-and-bank complex. The darker areas in the lower half of the photograph had been fenced and cultivated, sown to rye grass and surrounded by a shallow drain twelve years before the photograph was taken. The persistence of crabhole puffs in this enclosure is well shown. Some of this enclosed land was not cultivated because of its rocky nature; this part corresponds to two areas of thistle-zone just below the



Figs. 11 and 12.—Soil Maps corresponding to respective Photographs of Plate V. Signs have same meaning as on large map.  
Scale—Approx. 190 yards to 1 inch.





Portions of the Aerial Photograph.



centre of the photograph. Below this again, and surrounded by two narrow cultivated strips, is another patch which was left uncultivated because the rapid drying out of the soil had left it too difficult to deal with during the season in which the rest of the work was done.

### XI. Acknowledgments.

In making this study the writers have received assistance from many sources. Professor E. W. Skeats accompanied the party on two of its expeditions; his knowledge of the general geology of the area and of the Stony Rise country of the Western District in particular was of great value. Dr. R. T. Patton and Mr. H. C. Trumble helped with the identification of many of the plants. Mr. J. R. Freedman, B.Agr.Sc., was a member of the group during parts of 1933 and 1934, during which period he gave valuable assistance both in the field and laboratory. The labour of the work was reduced immeasurably by the kindness and courtesy of the Royal Australian Air Force in taking the aerial photographs and in making the mosaics. The Trustees of the Science and Industry Endowment Fund of the Commonwealth assisted by making grants to Miss Nicholls.

Finally the whole project would have been impracticable without the unfailing hospitality and interest of our hosts, Mr. and Mrs. R. A. Ramsay of "Mooleric," and Mr. and Mrs. Urquhart Ramsay of "Turkeith."

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### XIII. Names of Soil Types.

After consultation with Professor J. A. Prescott, the authors have assigned the following names to certain of the soil types here described:—

1. Corangamite stony loam.
3. Mooleric clay.
4. Grenville loam.
5. Grenville clay.
6. Grenville clay (swampy phase).
- 7 and 8. Turkeith clay.
9. Mount Gellibrand clay loam.

### Explanation of Plates.

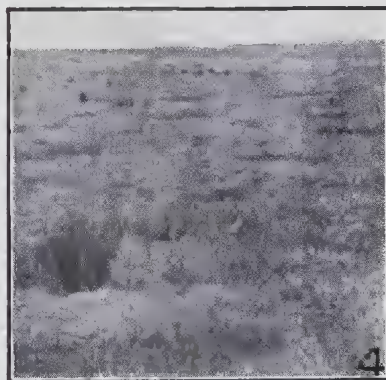
#### PLATE VI.

- Fig. 1. Trench under puff in crabhole formation. Note crumbly soil and patches of calcium carbonate near surface. The greyish-yellow calcareous horizon begins just above metallic part of spade.
- Fig. 2. Trench under depression two yards from Fig. 1. Horizontal cut marks the beginning of the greyish-yellow calcareous horizon, which is at the same level as the corresponding horizon in Fig. 1.
- Fig. 3. Stony rise, with thistle zone seen on skyline; in the foreground is a swampy patch with tussocks of *Poa caespitosa*.
- Fig. 4. Low slope, with incipient pan-and-bank formation.

#### PLATE VII.

- Fig. 1. Vegetation on a stony rise between boulders.
- Fig. 2. Vegetation on large drained clay pan (Type 6) in early stages of colonisation.
- Fig. 3. Vegetation on a rather poor low slope. *Danthonia semiannularis*, *Eryngium rostratum*, *Convolvulus erubescens*, and *Cuscuta epithymum* with many open spaces.
- Fig. 4. Vegetation of an undrained pan. *Danthonia semiannularis*, *Amphibromus nervosus*, and *Heliocharis acuta*.

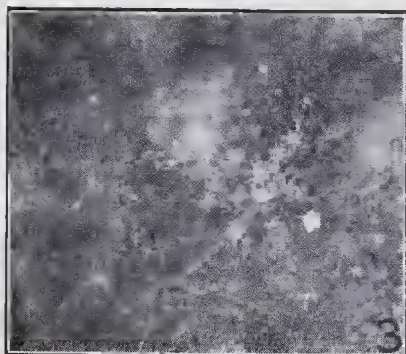
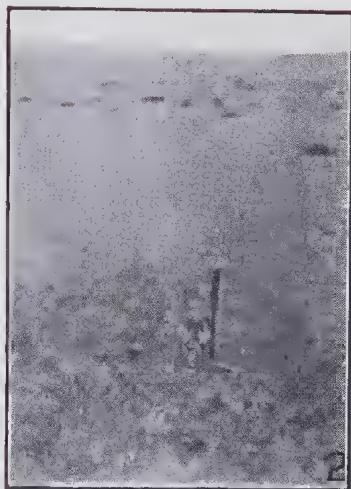
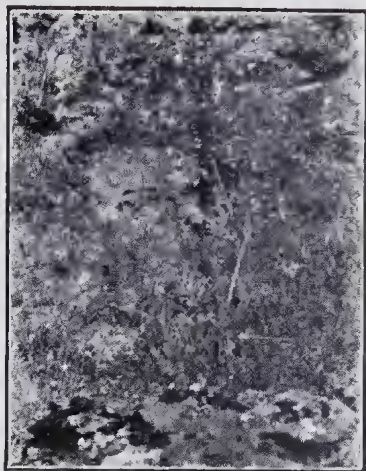




Features of Soil and Vegetation.







Typical Vegetation of the Area.

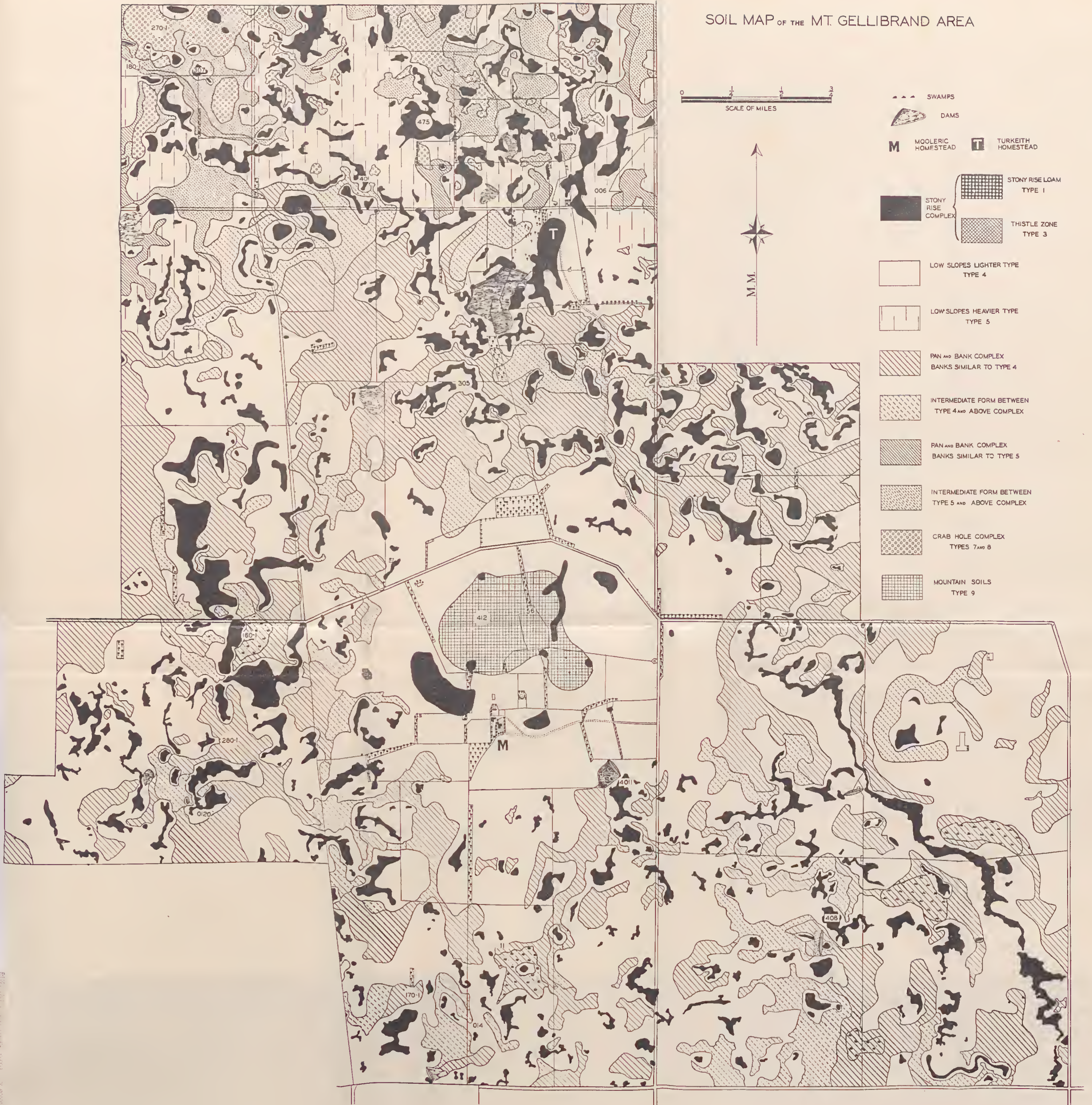




# SOIL MAP OF THE MT. GELLIBRAND AREA



- SWAMPS
- DAMS
- M MOOLERIC HOMESTEAD
- T TURKEITH HOMESTEAD
- STONY RISE COMPLEX
  - STONY RISE LOAM TYPE 1
  - THISTLE ZONE TYPE 3
- LOW SLOPES LIGHTER TYPE TYPE 4
- LOW SLOPES HEAVIER TYPE TYPE 5
- PAN AND BANK COMPLEX BANKS SIMILAR TO TYPE 4
- INTERMEDIATE FORM BETWEEN TYPE 4 AND ABOVE COMPLEX
- PAN AND BANK COMPLEX BANKS SIMILAR TO TYPE 5
- INTERMEDIATE FORM BETWEEN TYPE 5 AND ABOVE COMPLEX
- CRAB HOLE COMPLEX TYPES 7 AND 8
- MOUNTAIN SOILS TYPE 9









[PROC. ROY. SOC. VICTORIA, 49 (N.S.), Pt. I., 1936.]

ART. X.—*A Classification of the Foraminifera.*

By F. CHAPMAN, A.L.S., Hon. F.R.M.S., F.G.S., and  
W. J. PARR, F.R.M.S.

[Read 9th July, 1936; issued separately, 23rd November, 1936.]

### Introduction.

Until about the close of the period marked by the issue of Dr. H. B. Brady's monograph on the "Challenger" Foraminifera there was a gradual development of a plan of classification based primarily on the form of the test. This was of necessity an artificial method of classification, inasmuch as family names, such as Textulariidae, embraced both arenaceous and hyaline kinds; other families again had their plans of growth duplicated in adjacent ones.

Neumayr (1887) regarded the Astrorhizidae as the earliest forms; and, from this, three principal legions proceeded, the branches of the Miliolines, the Nodosarines and the Rotalines, each with their arenaceous isomorphs.

Ludwig Rhumbler (1895) made a great advance in classification, for he had closely studied the phylogenetic relationships of many of the genera. His conclusions are largely embodied in the latest classifications of Cushman and Galloway, and many are utilized in the present plan.

As Neumayr had already suggested, Rhumbler postulated that the most primitive forms were simple arenaceous tubes; these were succeeded by the sandy spiral tubes (Ammodiscidae) and, later, by the hyaline spiral forms (Spirillinidae). Rhumbler regarded the subarenaceous *Nodosinella* and the coiled and segmented *Endothyra*, as an offshoot from the sandy-tubed stock, which further passed into Rotaliidae and Nodosariidae.

Eimer and Fickert (1899) suggested a classification which was based on form only, the shell structure being regarded as merely of secondary importance. These morphological types were foreshadowed by d'Orbigny's earlier arrangement of Stichostegues, Helicostegues, &c.

Schubert (1907 and 1920) formulated a partial classification based both on morphology and phylogeny, and illustrated the relationships of several important groups.

A great advance was made, however, by Cushman (1925), who formulated a scheme partly based on the earlier work of Rhumbler and Schubert, and showed the affinities of the genera

much more completely than previous authors. This classification was completed in 1928 (Cushman, 1928). Cushman (1933, p. 54) rightly points out that "An ideal classification should be based upon the known phylogeny of a group as shown by the fossil record and coupled with the ontogeny of the individual, as shown in its complete development, together with what may be learned of the morphology and physiology of the group." He assumes that the simplest forms were chitinous, and from these myxothecid forms (Rhumbler), the sand-encrusted types were evolved with, later on, hyaline modifications. We are inclined to reverse this sequence, though the appearance of the two groups, hyaline and arenaceous, was almost simultaneous, as *Spirillina* and *Lituotuba* have been found by us in the Cambrian.

In Cushman's second edition (1933), many genera described since 1928 were included, and changes were made in the position of some of the earlier genera.

Galloway (1928, p. 224) points out, in regard to the sequence of the calcareous and arenaceous forms respectively, that "many chitinous and calcareous forms, some of the Lagenidae, Miliolidae and Rotaliidae, show a tendency to develop an agglutinated test on the chitinous or calcareous base, but no known foraminifera have an arenaceous young stage followed by a calcareous stage in its ontogeny." The results of detailed work amongst fossil forms have convinced us that the calcareous and arenaceous foraminifera were primarily derived from chitinous types. Of these two groups the hyaline must have appeared first if the test were naturally moulded on the protoplasm. This seems to be supported by the fact that the oldest representatives of the foraminifera (Lower Cambrian, of Nuneaton, England, and the Baltic) are found in the form of glauconite casts or grains, with the hyaline test often still adhering to them.

Galloway (1933) adopted the principles enunciated by Cushman, but, as a result of his interpretation of the phylogeny, the classification differs very considerably from those in previous publications. He regards "the families as derived from similar, but more primitive ancestors, rather than from arenaceous or tubular, or other specialized or degenerate forms."

The present authors differ from Cushman by grouping the arenaceous after the perforate calcareous types. We have placed the whole order in three super-families, viz., the Allogromioidea (chitinous), the Spirillinoidea (hyaline or perforate types), and the Ammodiscoidea (arenaceous, porcellaneous and subarenaceous forms).

A re-sorting of certain of Cushman's family groups has been made, and their number reduced where the generic relationships appear to warrant it. In any classification, the arrangement of families in sequence must be based on a more or less artificial plan, reticulated rather than divergent, as exemplified in the

same way in taxonomic arrangements of other groups of the animal kingdom. The inclusion of a larger number of genera within the family Rotaliidae is one of the more important changes. We have also regarded the family of the Nummulitidae as the most highly specialized of the foraminifera, in view of the complex canal system formed in the more highly developed genera. The genera constituting Cushman's sub-families Cassidulininae and Ehrenbergininae, in the family Cassidulinidae are here placed next to the Buliminidae, where it appears to us their affinities lie rather than in the Rotaliidae.

With a few minor exceptions, we have accepted the genera which Cushman has been at such pains to establish according to the rule of priority, but there are a few notable changes. The genus *Robulus* is merged into *Lenticulina*, on account of the inconstant character of the aperture. *Neusina*, *Jullienella* and *Rhaphidoscene* are omitted on account of their hydroid or spongoid affinities, whilst *Botellina*, formerly included in the family Neusinidae, here obliterated, is removed to the Rhizamminidae. In view of the constant stream of new genera still being published, it has been considered advisable to include only those which date to the end of 1934.

## Order FORAMINIFERA.

## Super-family ALLOGROMIOIDEA.

Family.	Sub-family.	Genus.	Time-range.
Fam. I.— ALLOGROMIDAE	Myxothecinae ..	<i>Schultesia</i> Rumbler, 1903 ..	Recent (Marine)
		<i>Myrotheca</i> Schaudian, 1893 ..	Recent (Marine)
		<i>Baderia</i> Strethill Wright, 1867 ..	Recent (Marine)
		<i>Plagiophrys</i> Claparède and Lachmann, 1859 ..	Recent (Freshwater)
		<i>Dactylosaccus</i> Rumbler, 1894 ..	Recent (Marine)
	Allogromiinae ..	<i>Allogromia</i> Rumbler, 1903 ..	Recent (Marine)
		<i>Lieberkühnia</i> Claparède and Lachmann, 1859 ..	Recent (Marine and Freshwater)
		<i>Shepherdella</i> Siddall, 1880 ..	Recent (Marine)
		<i>Rhynchosaccus</i> Rumbler, 1894 ..	Recent (Marine)
		<i>Rhynchogromia</i> Rumbler, 1894 ..	Recent (Marine and Freshwater)
		<i>Diplogromia</i> Rumbler, 1903 ..	Recent (Freshwater)
		<i>Diaphorodon</i> Archer, 1869 ..	Recent (Freshwater)
		<i>Amphitrema</i> Archer, 1870 ..	Recent (Freshwater)

## Super-family SPIRILLINOIDEA (ALL MARINE).

Family.	Sub-family.	Genus.	Time-range.
Fam. II.— SPIRILLINIDAE	.. ..	<i>Spirillina</i> Ehrenberg, 1843 ..	Cambrian—Recent
		<i>Archaeodiscus</i> Brady, 1873 ..	Carboniferous
		<i>Terebratina</i> Terquem, 1866 ..	Jurassic
		<i>Turrispirillina</i> Cushman, 1927 ..	Jurassic—Recent
		<i>Coniospirillina</i> Cushman, 1927 ..	Jurassic
		<i>Trocholina</i> Paalzow, 1922 ..	Jurassic
		<i>Paulzonella</i> Cushman, 1933 ..	Jurassic

## Super-family SPIRILLINOIDEA (ALL MARINE)—continued.

Family.	Sub-family.	Genus.	Time-range.	
Fam. III.— NODOSARIIDAE	Nodosariinae ..	<i>Lenticulina</i> Lamarek, 1804 ..	Upper Cambrian—Recent	
		<i>Planularia</i> DeFrance, 1824 ..	Jurassic—Recent	
		<i>Hemicristellaria</i> Stache, 1864 ..	Jurassic—Recent	
		<i>Saracenaria</i> DeFrance, 1824 ..	Jurassic—Recent	
		<i>Marginulina</i> d'Orbigny, 1826 ..	Upper Cambrian—Recent	
		<i>Vaginulina</i> d'Orbigny, 1826 ..	Jurassic—Recent	
		<i>Dentalina</i> d'Orbigny, 1826 ..	Jurassic—Recent	
		<i>Nodosaria</i> Lamarek, 1812 ..	Upper Cambrian—Recent	
		<i>Chrysalogonima</i> Schubert, 1907 ..	Cretaceous—Pliocene	
		<i>Pseudoglandulina</i> Cushman, 1929 ..	Jurassic—Recent	
		<i>Flabellina</i> d'Orbigny, 1839 ..	Jurassic—Recent	
		<i>Kyphopyra</i> Cushman, 1929 ..	Cretaceous	
		<i>Frondeularia</i> DeFrance, 1824 ..	Permian—Recent	
		<i>Geinitzina</i> Spandel, 1901 ..	Carboniferous and Permian	
		<i>Flabellinella</i> Schubert, 1907 ..	Upper Cretaceous	
		<i>Lingulina</i> d'Orbigny, 1826 ..	Permian—Recent	
		<i>Amphicoryne</i> Schlumberger, 1881 ..	Tertiary—Recent	
	Lageninae ..	<i>Lagena</i> Walker and Jacob, 1798 ..	? Upper Cambrian; Jurassic—Recent	
		(vel <i>Entosolenia</i> , Ehrenberg, 1848)		
Fam. IV.— POLY-MORPHINIDAE	Polymorphininae	<i>Eoguttulina</i> Cushman and Ozawa, 1930 ..	Jurassic—Cretaceous	
		<i>Quadrulina</i> Cushman and Ozawa, 1930 ..	Jurassic—Cretaceous	
		<i>Guttulina</i> d'Orbigny, 1826 (subgenus <i>Sigmoidina</i> Cushman and Ozawa, 1928) ..	Jurassic—Recent	
		<i>Pyridina</i> d'Orbigny, 1826 ..	Cretaceous—Recent	
		<i>Globulina</i> d'Orbigny, 1826 ..	Cretaceous—Recent	
		<i>Dimorphina</i> d'Orbigny, 1826 ..	Eocene—Lower Pliocene	
		<i>Pseudopolymorphina</i> Cushman and Ozawa, 1928 ..	Cretaceous—Recent	
		<i>Palaeopolymorphina</i> Cushman and Ozawa, 1930 ..	Cretaceous	
		<i>Polymorphina</i> d'Orbigny, 1826 ..	Eocene—Recent	
		<i>Sigmomorphina</i> Cushman and Ozawa, 1928 ..	Eocene—Recent	
	Ramulininae ..	<i>Sigmoidella</i> Cushman and Ozawa, 1928 ..	Eocene—Recent	
		<i>Glandulina</i> d'Orbigny, 1826 ..	Tertiary—Recent	
		<i>Ramulina</i> Rupert Jones, 1875 ..	Jurassic—Recent	
		<i>Vitreobina</i> Chapman, 1892 ..	Cretaceous—Eocene	
	Fam. V.— BULIMINIDAE	Turritininae ..	<i>Turritina</i> Andreae, 1884 (emend. Cushman, 1928) ..	Jurassic—Recent
			<i>Buliminella</i> Cushman, 1911 ..	Cretaceous—Recent
			<i>Buliminoides</i> Cushman, 1911 ..	Recent
		Bulimininae ..	<i>Robertina</i> d'Orbigny, 1846 ..	Recent
			<i>Bulimina</i> d'Orbigny, 1826 ..	Jurassic—Recent
<i>Neobulimina</i> Cushman and Wicken, 1928 ..			Cretaceous	
Virgulinae ..		<i>Globobulimina</i> Cushman, 1927 ..	Tertiary—Recent	
		<i>Virgulina</i> d'Orbigny, 1826 (subgenus <i>Virgulinella</i> Cushman, 1932) ..	Lower Cretaceous—Recent	
		<i>Bolivina</i> d'Orbigny, 1839 ..	Cretaceous—Recent	
Reussellinae ..		<i>Neobolivina</i> Cushman, 1927 ..	Tertiary—Recent	
		<i>Larostomum</i> Ehrenberg, 1854 ..	Cretaceous—Recent	
		<i>Tubulogenerina</i> Cushman, 1927 ..	Eocene—Miocene	
		<i>Bifurina</i> Parker and Jones, 1872 ..	Cretaceous—Recent	
		<i>Schubertina</i> A. Silvestri, 1911 ..	Tertiary and Recent	
		<i>Reussella</i> Galloway, 1933 ..	Cretaceous—Recent	
		<i>Mimosina</i> Millett, 1900 ..	Recent	
		<i>Trimosina</i> Cushman, 1927 ..	Recent	
		<i>Parosina</i> d'Orbigny, 1826 ..	Oligocene—Recent	
		<i>Chrysalidina</i> Schubert, 1907 ..	Miocene—Recent	
Uvigerininae ..	<i>Uvigerinella</i> Cushman, 1926 ..	Miocene—Recent		
	<i>Uvigerina</i> d'Orbigny, 1826 ..	Eocene—Recent		
	<i>Hopkinsina</i> Howe and Wallace, 1933 ..	Eocene—Recent		
	<i>Siphogenerina</i> Schlumberger, 1883 ..	Eocene—Recent		

## Super-family SPIRILLINOIDEA (ALL MARINE)—continued.

Family.	Sub-family.	Genus.	Time-range.
Fam. V.— BULIMINIDAE— continued.	Uvigerininae— continued.	<i>Siphonodosaria</i> A. Silvestri, 1924 .. <i>Anyulogerina</i> Cushman, 1927 .. <i>Trifarina</i> Cushman, 1923 .. <i>Dentalinopsis</i> Reuss, 1860 .. <i>Sporadogenerina</i> Cushman, 1927 ..	Tertiary—Recent Eocene—Recent ? Cretaceous; Eocene—Recent Cretaceous Recent
Fam. VI.— CASSIDULINIDAE	..	<i>Cassidulina</i> d'Orbigny, 1826 .. <i>Cassidulinoides</i> Cushman, 1927 .. <i>Pseudobulimina</i> Earland, 1934 .. <i>Orthoplecta</i> Brady, 1884 .. <i>Ehrenbergina</i> Reuss, 1850 ..	Upper Cretaceous—Recent Eocene—Recent Recent Recent Eocene—Recent
Fam. VII.— PLEURO- STOMELLIDAE	..	<i>Pleurostomella</i> Reuss, 1860 .. <i>Pleurostomellina</i> Schubert, 1911 .. <i>Ellipsopleurostomella</i> A. Silvestri, 1903 <i>Ellipsobulimina</i> A. Silvestri, 1903 <i>Notosarella</i> Rzehak, 1895 .. <i>Ellipsotungulina</i> A. Silvestri, 1907 <i>Ellipsobulandina</i> A. Silvestri, 1900 <i>Goniatosphaera</i> Guppy, 1894 .. <i>Ellipsoidina</i> Seguenza, 1859 .. <i>Ellipsotagena</i> A. Silvestri, 1923 ..	Cretaceous—Recent Upper Cretaceous Cretaceous and Tertiary Miocene Cretaceous and Tertiary Tertiary Cretaceous and Tertiary Tertiary Cretaceous and Tertiary Tertiary—Recent
Fam. VIII.— HETERO- HELICIDAE	Heterohelicinae	<i>Heterohelix</i> Ehrenberg, 1843 .. <i>Spiroplectoides</i> Cushman, 1927 ..	Cretaceous Cretaceous—Recent
	Gümbelinae	<i>Gumbelina</i> Egger, 1899 .. <i>Gumbelittia</i> Cushman, 1933 .. <i>Rectogumbelina</i> Cushman, 1932 .. <i>Tubulitularia</i> Sulc, 1929 .. <i>Pseudotectularia</i> Rzehak, 1886 ..	Cretaceous—Eocene Upper Cretaceous Upper Cretaceous Upper Cretaceous Upper Cretaceous—Lower Eocene
	Bolivinitinae	<i>Planoglobulina</i> Cushman, 1927 .. <i>Ventilabrella</i> Cushman, 1928 .. <i>Bolivinaoides</i> Cushman, 1927 .. <i>Bolivina</i> Cushman, 1927 .. <i>Bolivina</i> Cushman, 1927 ..	Upper Cretaceous Upper Cretaceous Upper Cretaceous Upper Cretaceous—Recent Eocene—Recent
	Plectofrondiculariinae	<i>Plectofrondicularia</i> Liebus, 1903 .. <i>Amphimorphina</i> Nengeboren, 1850 <i>Nadomorphina</i> Cushman, 1927 ..	Cretaceous—Recent Miocene—Pliocene Miocene—Pliocene
	Eouvigerininae	<i>Eouvigerina</i> Cushman, 1926 .. <i>Pseudouvigerina</i> Cushman, 1927 .. <i>Siphogenerinoides</i> Cushman, 1927 .. <i>Nadogenerina</i> Cushman, 1927 ..	Upper Cretaceous Upper Cretaceous—Eocene Upper Cretaceous Cretaceous—Recent
Fam. IX.— ROTALIIDAE	Discorbiniae	<i>Patellina</i> Williamson, 1858 .. <i>Patellinoides</i> Heron-Allen and Earland, 1932 <i>Ungulatella</i> Cushman, 1931 .. <i>Patellinella</i> Cushman, 1928 .. <i>Annulopatellina</i> Parr and Collins, 1930 <i>Discorbia</i> Lamarck, 1804 .. <i>Heronallenia</i> Chapman and Parr, 1931	Permian—Recent Recent Lower Miocene—Recent Lower Miocene—Recent Jurassic—Recent Upper Oligocene—Recent
	Cymbaloporinae	<i>Lamarckina</i> Berthelin, 1881 .. <i>Valmulinaria</i> Cushman, 1926 .. <i>Ceratobulimina</i> Toulle, 1920 .. <i>Cymbalopora</i> Hagenow, 1851 .. <i>Cymbaloporella</i> Cushman, 1927 .. <i>Tretamphalus</i> Moeblus, 1880 .. <i>Pyropilus</i> Cushman, 1934 .. <i>Gyroidina</i> d'Orbigny, 1826 .. <i>Rotatolina</i> Cushman, 1925 .. <i>Eponides</i> Montfort, 1808 ..	Upper Cretaceous—Recent Cretaceous—Recent Upper Cretaceous—Recent Cretaceous—Recent Eocene—Recent Recent Recent Eocene—Recent Eocene ? Carboniferous; Jurassic—Recent
	Rotallinae	<i>Planopulvinulina</i> Schubert, 1920 ..	Late Tertiary—Recent



## Super-family SPIRILLINOIDEA (ALL MARINE)—continued.

Family.	Sub-family.	Genus.	Time-range.
Fam. IX.— ROTALIIDAE— continued.	Rotaliine— —continued.	<i>Pulvinulinella</i> Cushman, 1926 ..	Cretaceous—Recent
		<i>Rotalia</i> Lamarck, 1804 ..	Cretaceous—Recent
		<i>Loekhartia</i> L. M. Davies, 1932 ..	Eocene
		<i>Dietyconoides</i> Nuttall, 1925 ..	Eocene
	Pegidiinae ..	<i>Rugidia</i> Heron-Allen and Earland, 1928 ..	Recent
		<i>Pegidia</i> Heron-Allen and Earland, 1928 ..	Miocene—Recent
		<i>Sphaeridia</i> Heron-Allen and Earland, 1928 ..	Recent
		<i>Physalidia</i> Heron-Allen and Earland, 1928 ..	Recent
	Siphonininae ..	<i>Epistomina</i> Terquem, 1883 ..	Jurassic—Recent
		<i>Epistominoides</i> Plummer, 1934 ..	Eocene
		<i>Epistomaria</i> Galloway, 1933 ..	Eocene—Recent
		<i>Mississippina</i> Howe, 1930 ..	Lower Oligocene—Recent
		<i>Calceus</i> Plummer, 1934 ..	Eocene
		<i>Siphonina</i> Reuss, 1849 ..	Cretaceous—Recent
		<i>Siphonamides</i> Cushman, 1927 ..	Tertiary—Recent
		<i>Siphoninella</i> Cushman, 1927 ..	Eocene—Recent
	Baggiuinae ..	<i>Caneis</i> Montfort, 1808 ..	Tertiary—Recent
		<i>Baggina</i> Cushman, 1926 ..	Miocene—Recent
		<i>Neocorbella</i> Cushman, 1928 ..	Eocene
	Cibicidinae ..	<i>Anomulina</i> d'Orbigny, 1826 ..	Lower Cretaceous—Recent
		<i>Planulina</i> d'Orbigny, 1826 ..	Cretaceous—Recent
		<i>Laticarinina</i> Galloway and Wissler, 1928 ..	Eocene—Recent
		<i>Anomulinella</i> Cushman, 1927 ..	? Miocene—Recent
		<i>Cibicides</i> Montfort, 1808 ..	Cretaceous—Recent
		<i>Rectocibicides</i> Cushman and Ponton, 1932 ..	Miocene—Recent
		<i>Dyocibicides</i> Cushman and Valentine, 1930 ..	Miocene—Recent
		<i>Cydocibicides</i> Cushman, 1927 ..	Recent
		<i>Anadacibicides</i> Cushman and Ponton, 1932 ..	Miocene
		<i>Cibicidella</i> Cushman, 1927 ..	Recent
		<i>Webbia</i> d'Orbigny, 1839 (cf. <i>Placopsina</i> Rumbler, 1913) ..	Recent
		<i>Planorbulina</i> d'Orbigny, 1826 ..	Eocene—Recent
		<i>Planorbulinoides</i> Cushman, 1928 ..	Recent
		<i>Planorbulinella</i> Cushman, 1927 ..	Eocene—Recent
		<i>Linderina</i> Schlumberger, 1893 ..	Upper Eocene
		<i>Langhanina</i> Palmer, 1934 ..	Upper Cretaceous
		<i>Chapmanina</i> A. Silvestri, 1931 ..	Eocene
		<i>Halkyardia</i> Heron-Allen and Earland, 1919 ..	Eocene—Lower Miocene
		(The position of the four preceding genera is uncertain, and they may belong to the Orbitoididae.)	
		<i>Acerrulina</i> Schultze, 1854 ..	Oligocene—Recent
		<i>Gypsina</i> Carter, 1877 ..	Cretaceous—Recent
	Rupertiinae ..	<i>Rupetia</i> Wallich, 1877 ..	Eocene—Recent
		<i>Carpenteria</i> Gray, 1858 ..	Cretaceous—Recent
		<i>Eorupetia</i> Yabe and Hanzawa, 1927 ..	Eocene
		<i>Victoriella</i> Chapman and Crespin, 1930 ..	Oligocene—Lower Miocene
		<i>Hofkerina</i> Chapman and Parr, 1931 ..	Lower Miocene
	Homotreminae ..	<i>Homotrema</i> Hickson, 1911 ..	Recent
		<i>Sporadotrema</i> Hickson, 1911 ..	Lower Miocene—Recent
	Amphistegininae	<i>Minaquina</i> Galloway, 1933 ..	Lower Miocene—Recent
		<i>Asterigerina</i> d'Orbigny, 1839 ..	Eocene—Recent
		<i>Amphistegina</i> d'Orbigny, 1826 ..	Eocene—Recent
	Calcarininae ..	<i>Calcarina</i> d'Orbigny, 1826 ..	Cretaceous—Recent
		<i>Siderolites</i> Lamarck, 1801 ..	Cretaceous—Recent
		<i>Baculogypsinoides</i> Yabe and Hanzawa 1930 ..	Eocene—Recent
		<i>Pellatispira</i> Boussac, 1906 ..	Eocene
		<i>Baculogypsina</i> Sacco, 1893 ..	Upper Miocene—Recent
		<i>Arnaudicella</i> H. Douville, 1907 ..	Uppermost Cretaceous

## Super-family SPIRILLINOIDEA (ALL MARINE)—continued.

Family.	Sub-family.	Genus.	Time-range.
Fam. X.— CHILOSTO- MELLIDAE	Chilostomellinae	<i>Allomorphina</i> Reuss, 1850 ..	Upper Cretaceous—Recent
		<i>Chilostomella</i> Reuss, 1850 ..	Upper Cretaceous—Recent
		<i>Chilostomelloides</i> Cushman, 1926 ..	Upper Cretaceous—Miocene
	Seabrookiinae ..	<i>Seabrookia</i> Brady, 1890 ..	Recent
	Allomorphinellinae	<i>Allomorphinella</i> Cushman, 1927 ..	Upper Cretaceous
		<i>Chilostomellina</i> Cushman, 1926 ..	Recent
Fam. XI.— ORBULINIDAE		<i>Pullenia</i> Parker and Jones, 1862 ..	Cretaceous—Recent
	Sphaeroidininae	<i>Sphaeroidina</i> d'Orbigny, 1826 ..	Cretaceous—Recent
	Globigerininae ..	<i>Globigerina</i> d'Orbigny, 1826 ..	Cretaceous—Recent
		<i>Globigerinoides</i> Cushman, 1927 ..	Tertiary—Recent
		<i>Globigerinella</i> Cushman, 1927 ..	Cretaceous—Recent
		<i>Hastigerina</i> Wyville Thomson, 1876 ..	Miocene—Recent
		<i>Hastigerinella</i> Cushman, 1927 ..	Upper Cretaceous—Recent
	Orbulininae ..	<i>Orbulina</i> d'Orbigny, 1826 ..	Tertiary—Recent
	Pulleniatininae	<i>Pulleniatina</i> Cushman, 1927 ..	Oligocene—Recent
		<i>Sphaeroidinella</i> Cushman, 1927 ..	Eocene—Recent
	Candeininae ..	<i>Candeina</i> d'Orbigny, 1839 ..	Late Tertiary—Recent
	Hantkenininae	<i>Scharckina</i> Thalman, 1932 ..	Upper Cretaceous
		<i>Hantkenina</i> Cushman, 1924 ..	Middle and Upper Eocene
	Globorotalinae	<i>Globorotalina</i> Cushman, 1927 ..	Upper Cretaceous—Recent
		<i>Globorotalia</i> Cushman, 1927 ..	Upper Cretaceous—Recent
		<i>Cyclolobulina</i> Heron-Allen and Earland, 1908 ..	Eocene
		<i>Sherbornina</i> Chapman, 1922 ..	Lower Miocene
Fam. XII.— ORBITOIDIDAE	Lepidorbitoidinae	<i>Monolepidorbita</i> Astre, 1927 ..	Upper Cretaceous
		<i>Lepidorbitoides</i> A. Silvestri, 1907 ..	Upper Cretaceous
	Orbitoidinae ..	<i>Clipporbis</i> H. Douvillé, 1915 ..	Upper Cretaceous
		<i>Orbitoides</i> d'Orbigny, 1847 ..	Upper Cretaceous
		<i>Simplorbites</i> de Gregorio, 1882 ..	Upper Cretaceous
		<i>Astinosiphon</i> Vaughan, 1929 ..	Lower Eocene
		<i>Pseudorbitoides</i> H. Douvillé, 1922 ..	Upper Cretaceous
		<i>Orbitocyclina</i> Vaughan, 1929 ..	Upper Cretaceous
		<i>Asterorbis</i> Vaughan and Cole, 1932 ..	Upper Cretaceous
		<i>Lepidocyclina</i> Gümbel, 1868 ..	Middle Eocene—Middle Miocene
		S.G. <i>Polytepidina</i> Vaughan, 1924 ..	Middle and Upper Eocene
		S.G. <i>Multitepidina</i> Hanzawa, 1932 ..	Lower Miocene
		S.G. <i>Pliotepidina</i> H. Douvillé, 1915 ..	Upper Eocene
		S.G. <i>Lepidocyclina</i> Gümbel, 1868 ..	Upper Eocene—Lower Miocene
		S.G. <i>Nephrolepidina</i> H. Douvillé, 1911 ..	Upper Eocene—Middle Miocene
		S.G. <i>Eutepidina</i> H. Douvillé, 1911 ..	Middle Oligocene—Lower Miocene
	Omphalocyclinae	<i>Omphalocyclus</i> Broun, 1852 ..	Upper Cretaceous
	Miogypsininae ..	<i>Miogypsina</i> Sacco, 1893 ..	Oligocene—Pliocene
		<i>Miogypsinoides</i> Yabe and Hanzawa, 1928 ..	Lower Miocene
	Discocyclinae	<i>Heterolepidina</i> Tobler, 1922 ..	Upper Eocene
		<i>Discocyclina</i> Gümbel, 1868 ..	Upper Cretaceous (Danian)—Upper Eocene
		S.G. <i>Aktinocyclina</i> Gümbel, 1863 ..	Middle and Upper Eocene
		S.G. <i>Asterocyclina</i> Gümbel, 1868 ..	Middle and Upper Eocene
		(vel <i>Orthocyclina</i> van der Vlerk, 1923)	
Fam. XIII.— NUMMULITIDAE	Nonioninae ..	<i>Nonion</i> Montfort, 1808 ..	Jurassic—Recent
		<i>Nonionella</i> Cushman, 1926 ..	Cretaceous—Recent
		<i>Elyphidina</i> Montfort, 1808 ..	Jurassic—Recent
		<i>Polystomellina</i> Yabe and Hanzawa, 1923 ..	Tertiary—Recent
		<i>Faujasina</i> d'Orbigny, 1839 ..	Cretaceous—Recent
	Nummulitinae ..	<i>Nummulites</i> Lamarck, 1801 ..	Eocene—Oligocene
		<i>Axillina</i> d'Orbigny, 1826 ..	Eocene
		<i>Operculinella</i> Yabe, 1918 ..	Lower Miocene—Recent
		<i>Operculina</i> d'Orbigny, 1826 ..	Lower Cretaceous—Recent
		<i>Heterostegina</i> d'Orbigny, 1826 ..	Eocene—Recent
		<i>Spirocyclus</i> H. Douvillé, 1905 ..	Lower Miocene
		<i>Heterocyclus</i> Schubert, 1906 ..	Tertiary
		<i>Cyclocyclus</i> Carpenter, 1856 ..	Eocene—Recent.

Super-family AMMODISCOIDEA (ALL MARINE except the genus *Entzia*, which occurs in salt pools of Hungary).

Family.	Sub-family.	Genus.	Time-range.		
Fam. XIV.— AMMODISCIDAE	Ammodiscinae	<i>Ammodiscus</i> Reuss, 1861 ..	Silurian—Recent		
		<i>Hemidiscus</i> Schellwien, 1898 ..	Carboniferous—Recent		
		<i>Turritelletta</i> Rhumbler, 1903 ..	Carboniferous—Recent		
		<i>Howchinia</i> Cushman, 1927 ..	Carboniferous		
		<i>Ammodiscoides</i> Cushman, 1909 ..	Carboniferous—Recent		
		<i>Glomospira</i> Kzebak, 1888 ..	Carboniferous—Recent		
	Tolypammininae	<i>Lituolaba</i> Rhumbler, 1895 ..	Cambrian—Recent		
		<i>Psammomyx</i> Döderlein, 1892 ..	Recent		
		<i>Tolypammina</i> Rhumbler, 1895 ..	Carboniferous—Recent		
		<i>Ammodiscella</i> Cushman 1928 ..	Carboniferous—Jurassic		
		<i>Ammodiscigena</i> Elmer and Fickert, 1899 ..	Carboniferous—Recent		
		<i>Trepelopsis</i> Cushman and Waters, 1928 ..	Carboniferous		
Fam. XV.— HYPERAMMINIDAE	Hyperammininae	<i>Hyperammina</i> Brady, 1878 ..	Cambrian (?), Silurian—Recent		
		<i>Hyperamminoides</i> Cushman and Waters, 1928 ..	Upper Carboniferous		
		<i>Earlandia</i> Plummer, 1930 ..	Upper Carboniferous		
		<i>Jaculella</i> Brady, 1879 ..	Miocene—Recent		
	Dendrophryinae	<i>Hippocrepina</i> Parker, 1870 ..	Upper Carboniferous, Pliocene—Recent		
		<i>Nubeculariella</i> Awerinzew, 1911 ..	Recent		
		<i>Normania</i> Cushman, 1928 ..	Recent		
		<i>Saccorhiza</i> Elmer and Fickert, 1899 ..	Jurassic—Recent		
		<i>Dendrophrya</i> Strehill Wright, 1861 ..	Cretaceous—Recent		
		<i>Dendronina</i> Heron-Allen and Earland, 1922 ..	Recent		
		<i>Holiphysema</i> Bowerbank, 1862 ..	Recent		
		<i>Sagetta</i> Chapman, 1900 ..	Eocene—Recent		
		<i>Psammotodendron</i> Norman, 1881 ..	Recent		
		<i>Syringammina</i> Brady, 1883 ..	Recent		
		<i>Ophiolaba</i> Rhumbler, 1894 ..	Recent		
		<i>Dendrotaba</i> Rhumbler, 1894 ..	Recent		
		Fam. XVI.— SACCAMMINIDAE	Psammospira	<i>Psammospira</i> F. E. Schulze, 1875 ..	Silurian—Recent
				<i>Blastammina</i> Eisenack, 1932 ..	Silurian
				<i>Sorosphaera</i> Brady, 1879 ..	Silurian—Recent
				<i>Psammophax</i> Rhumbler, 1931 ..	Recent
			Saccammininae	<i>Storthospira</i> F. E. Schulze, 1875 ..	Middle Oligocene—Recent
				<i>Saccamina</i> M. Sars, 1869 ..	Recent
<i>Proconina</i> Williamson, 1858 ..	Carboniferous—Recent				
<i>Brachysiphon</i> Chapman, 1906 ..	Recent				
<i>Lagenammina</i> Rhumbler, 1911 ..	Silurian—Recent				
<i>Lagenunculina</i> Rhumbler, 1903 ..	Recent				
<i>Milottella</i> Rhumbler, 1903 ..	Miocene—Recent				
<i>Marsupulina</i> Rhumbler, 1903 ..	Recent				
<i>Urnulina</i> Gruber, 1884 ..	Miocene—Recent				
<i>Pseudarcella</i> Spandel, 1909 ..	Oligocene and Miocene				
Pelosininae	<i>Ammosphaeroides</i> Cushman, 1910 ..		Recent		
	<i>Thurammina</i> Brady, 1879 ..		Silurian—Recent		
	<i>Pelosina</i> Brady, 1879 ..		Carboniferous—Recent		
	<i>Techadella</i> Norman, 1878 ..		Recent		
	<i>Pilulina</i> Carpenter, 1870 ..		Recent		
	<i>Protobottellina</i> Heron-Allen and Earland, 1929 ..		Recent		
	Webbiniellinae	<i>Webbiniella</i> Rhumbler, 1903 ..	Carboniferous—Recent		
		<i>Colonammina</i> Moreman, 1930 ..	Lower Palaeozoic, America		
<i>Tholostina</i> Rhumbler, 1895 ..		Silurian—Recent			
<i>Verrucina</i> Goes, 1896 ..		Recent			
Fam. XVII.— RHIZAMMINIDAE	Rhizammininae	<i>Urnula</i> Wicner, 1931 ..	Recent		
		<i>Rhizammina</i> Brady, 1879 ..	Cretaceous—Recent		
		<i>Marsipella</i> Norman, 1878 ..	Jurassic—Recent		
		<i>Bathysiphon</i> M. Sars, 1872 ..	Silurian, Cretaceous—Recent		
	Botellininae	<i>Hippocrepinella</i> Heron-Allen and Earland, 1932 ..	Recent		
		<i>Botellina</i> Carpenter, 1869 ..	Recent		
		<i>Schizammina</i> Heron-Allen and Earland, 1929 ..	Recent		

## Super-family AMMODISCOIDEA—continued.

Family.	Sub-family.	Genus.	Time-range.
Fam. XVIII.— ASTORRHIZIDAE	.. ..	<i>Astorrhiza</i> Sandahl, 1858 ..	Jurassic—Recent
		<i>Pseudastorrhiza</i> Eisenack, 1932 ..	Silurian
		<i>Masonella</i> Brady, 1889 ..	Recent
		<i>Rhabdammina</i> M. Sars, 1869 ..	Jurassic—Recent
		<i>Crithionina</i> Goës, 1894 ..	Silurian—Recent
		<i>Iridia</i> Heron-Allen and Earland, 1914 ..	Eocene (?)—Recent
		<i>Vanhoeffenella</i> Rhumbler, 1905 ..	Recent
		<i>Astrammina</i> Rhumbler, 1931 ..	Recent
		<i>Arnorella</i> Heron-Allen and Earland, 1932 ..	Recent
		<i>Protosphaera</i> Heron-Allen and Earland, 1932 ..	Recent
Fam. XIX.— OPHTHAL- MIDIIDAE	Cornuspirinae ..	<i>Cornuspira</i> Schultze, 1854 ..	Carboniferous—Recent
		<i>Reolocornuspira</i> Warthin, 1930 ..	Upper Carboniferous
		<i>Vidalina</i> Schlumberger, 1899 ..	Cretaceous
		<i>Hemigordius</i> Schubert, 1908 ..	Upper Carboniferous—Permian
		<i>Gordiaspira</i> Heron-Allen and Earland, 1932 ..	Recent
		<i>Orthoretella</i> , Cushman and Waters, 1928 ..	Upper Carboniferous
		<i>Calciornella</i> Cushman and Waters, 1928 ..	Upper Carboniferous—Permian
		<i>Calcioretella</i> Cushman and Waters, 1928 ..	Upper Carboniferous
		<i>Plummerinella</i> Cushman and Waters, 1928 ..	Upper Carboniferous
		<i>Apterrinella</i> Cushman and Waters, 1928 ..	Upper Carboniferous
		<i>Cornuspiramia</i> Cushman, 1928 ..	Recent
	Nodobaculariinae	<i>Cornuspirella</i> Cushman, 1928 ..	Recent
		<i>Cornuspiroides</i> Cushman, 1928 ..	Recent
		<i>Nodobacularia</i> Rhumbler, 1895 ..	Lias—Recent
	Ophthalmidifinae	<i>Vertebrulina</i> d'Orbigny, 1826 ..	Eocene—Recent
		<i>Ophthalmidium</i> Zwingli and Kübler, 1870 ..	Jurassic—Recent
		<i>Spirophthalmidium</i> Cushman, 1927 ..	Jurassic—Recent
		<i>Discospirina</i> Munier-Chalmas, 1902 ..	Tertiary—Recent
		<i>Planispirina</i> Seguenza, 1880 ..	Cretaceous—Recent
		<i>Renssella</i> Lamarck, 1804 ..	Eocene
		<i>Planispirinella</i> Wiesner, 1931 ..	Miocene—Recent
		<i>Wiesnerella</i> Cushman, 1933 ..	Recent
		<i>Trisegmentina</i> Wiesner, 1931 ..	Recent
		<i>Nubecularia</i> DeFrance, 1825 ..	Jurassic—Recent
	Nubeculariinae	<i>Nubeculinella</i> Cushman, 1929 ..	Jurassic
		<i>Sinzynella</i> Cushman, 1933 ..	Miocene
		<i>Coelotuba</i> Roboz, 1884 ..	Recent
		<i>Parrina</i> Cushman, 1931 ..	Recent
		<i>Agathammina</i> Neumayr, 1887 ..	Carboniferous—Jurassic
		<i>Quaquebuculina</i> d'Orbigny, 1826 ..	Carboniferous—Recent
		<i>Massilina</i> Schlumberger, 1893 ..	Lower Cretaceous—Recent
Fam. XX.— MILIOLIDAE	.. ..	<i>Spiroloculina</i> d'Orbigny, 1826 ..	Jurassic—Recent
		<i>Sipmollina</i> Schlumberger, 1887 ..	Tertiary—Recent
		<i>Nansanloculina</i> Steinmann, 1881 ..	Jurassic—Recent
		<i>Articulina</i> d'Orbigny, 1826 ..	Lower Eocene—Recent
		<i>Tubicella</i> Rhumbler, 1906 ..	Lower Miocene—Recent
		<i>Nubeculina</i> Cushman, 1924 ..	Recent
		<i>Ptychomiliola</i> Elmer and Fickert, 1899 ..	Recent
		<i>Miliola</i> Lamarck, 1804 ..	Eocene—Lower Miocene
		<i>Heterillina</i> Munier-Chalmas and Schlumberger, 1905 ..	Upper Eocene—Oligocene
		<i>Hauerina</i> d'Orbigny, 1839 ..	Eocene—Recent
		<i>Schlumbergerina</i> Munier-Chalmas, 1882 ..	Late Tertiary—Recent
		<i>Ammonassilina</i> Cushman, 1933 ..	Recent
		<i>Tribiculina</i> d'Orbigny, 1826 ..	Triassic—Recent
		<i>Trullina</i> Munier-Chalmas, 1882 ..	Eocene—Lower Miocene
		<i>Platina</i> Cushman, 1921 ..	Recent
		<i>Purgo</i> DeFrance, 1824 ..	Jurassic—Recent
		<i>Fabularia</i> DeFrance, 1820 ..	Eocene—Lower Pliocene

## Super-family AMMODISCOIDEA—continued.

Family.	Sub-family.	Genus.	Time-range.
Fam. XX.— MILICOLIDAE— continued.	.. ..	<i>Flintia</i> Schubert, 1911 .. .. <i>Nerillina</i> Sichelottou, 1905 .. .. <i>Idalina</i> Munier-Chalmas and Schlumberger, 1884 .. .. <i>Periloricina</i> Munier-Chalmas and Schlumberger, 1885 .. .. <i>Lacazina</i> Munier-Chalmas, 1882 .. ..	Tertiary—Recent Recent Upper Cretaceous Upper Cretaceous Upper Cretaceous
Fam. XXI.— FISCHERINIDAE	.. ..	<i>Fischerina</i> Terquem, 1878 .. ..	Pliocene—Recent
Fam. XXII.— SORITIDAE	Peneroplinae ..	<i>Peneroplis</i> Montfort, 1808 .. .. <i>Dendritina</i> d'Orbigny, 1826 .. .. <i>Spicolina</i> Lamarck, 1804 .. .. <i>Monalysidium</i> Chapman, 1900 .. ..	Eocene—Recent Eocene—Recent Eocene—Recent Recent
	Archaiasinae ..	<i>Archaias</i> Montfort, 1808 .. ..	Miocene—Recent
	Orbitolininae ..	<i>Fullotia</i> H. Douvillé, 1902 .. .. <i>Orbitolites</i> Lamarck, 1801 .. .. <i>Opertorbitolites</i> Nuttall, 1925 .. .. <i>Anaphisorus</i> Ehrenberg, 1840 .. .. <i>Sorites</i> Ehrenberg, 1840 .. .. <i>Marginopora</i> Blainville, 1830 .. .. Genera of doubtful relationships. <i>Craterites</i> Heron-Allen and Earland, 1924 .. .. <i>Broeckina</i> Munier-Chalmas, 1882 .. .. <i>Meodutropsina</i> Munier-Chalmas, 1899 .. .. <i>Pruesorites</i> H. Douvillé, 1902 .. .. <i>Rhaphidionina</i> Stache, 1912 .. .. <i>Rhapidionina</i> Stache, 1912 .. ..	Upper Cretaceous Upper Cretaceous Eocene Eocene Eocene Oligocene—Recent Miocene—Recent Late Tertiary—Recent Recent Upper Cretaceous Upper Cretaceous Upper Cretaceous Lower Eocene Lower Eocene
Fam. XXIII.— ALVEOLINEL- LIDAE	.. ..	<i>Borelis</i> Montfort, 1808 .. .. <i>Fasciobites</i> Parkinson, 1811 .. .. <i>Floresulina</i> Stache, 1883 .. .. <i>Floresulinella</i> Schubert, 1910 .. .. <i>Alveolinella</i> H. Douvillé, 1906 .. ..	Eocene—Recent Cretaceous—Miocene Eocene Oligocene—Miocene Upper Miocene—Recent
Fam. XXIV.— KERAMO- SPHAERIDAE	.. ..	<i>Keramosphaera</i> Brady, 1882 .. ..	Recent
Fam. XXV.— SILICINIDAE	Siliciniinae ..	<i>Sicelina</i> Bornemann, 1874 .. .. <i>Lacolutina</i> Terquem, 1862 .. .. <i>Problematica</i> Bornemann, 1874 .. .. <i>Rzechakina</i> Cushman, 1927 .. ..	Lias Jurassic Jurassic Upper Cretaceous— Eocene
	Rzechakiniinae ..	<i>Silicosignatolina</i> Cushman and Church, 1929 .. .. <i>Mitiammina</i> Heron-Allen and Ear- land, 1930 .. .. <i>Spiroloraminina</i> Earland, 1934 .. ..	Upper Cretaceous Recent Recent
Fam. XXVI.— LITUOLIDAE	Endothyriinae ..	<i>Endothyra</i> Phillips, 1846 .. .. <i>Bradyina</i> Möller, 1878 .. .. <i>Glyphostomella</i> Cushman and Waters, 1928 .. .. <i>Cribraspira</i> Möller, 1878 .. .. <i>Endothyranella</i> Galloway and Har- ton, 1930 .. ..	Carboniferous—Trias Carboniferous Upper Carboniferous Carboniferous Carboniferous
	Haplophrag- miinae ..	<i>Ammostrophia</i> Earland, 1934 .. .. <i>Trochamminoides</i> Cushman, 1910 .. .. <i>Haplophragmoides</i> Cushman, 1910 .. .. <i>Recurviroles</i> Earland, 1934 .. .. <i>Orbitana</i> Hagenow, 1842 .. .. <i>Cribrastomoides</i> Cushman, 1910 .. .. <i>Ammonatrymbula</i> Wiesner, 1931 .. .. <i>Ammonatrymbula</i> Cushman, 1910 .. .. <i>Phlebotammina</i> Cushman, 1928 .. .. <i>Frankina</i> Cushman and Alexander, 1929 .. .. <i>Triplasia</i> Reuss, 1854 .. .. <i>Haplophragmium</i> Reuss, 1860 .. ..	Recent Carboniferous—Recent Carboniferous—Recent Recent Cretaceous Cretaceous—Recent Cretaceous—Recent Carboniferous—Recent Cretaceous Cretaceous Cretaceous—Recent



## Super-family AMMODISCOIDEA—continued.

Family.	Sub-family.	Genus.	Time-range.
Fam. XXVI.— LITUOLIDAE— continued.	Lituolinae ..	<i>Discammina</i> Lacroix, 1932 .. <i>Cyclammina</i> Brady, 1876 .. <i>Pseudocyclammina</i> Yabe and Hanzawa, 1926 .. <i>Choffatella</i> Schumberger, 1904 .. <i>Dictyopsella</i> Munier-Chalmas, 1899 .. <i>Vaherinella</i> Vaughan, 1928 .. <i>Lituola</i> Lamarek, 1804 .. <i>Spirocyclina</i> Munier-Chalmas, 1887 .. <i>Cyclotina</i> d'Orbigny, 1846 .. <i>Orbitopsella</i> Munier-Chalmas, 1902 .. <i>Cyclopsinella</i> Galloway, 1933 ..	Recent Cretaceous—Recent Cretaceous Jurassic and Cretaceous Upper Cretaceous Middle Eocene Carboniferous—Recent Upper Jurassic—Cretaceous Cretaceous Jurassic Upper Cretaceous Silurian—Recent Recent Jurassic—Recent Recent
	Placopsilininae ..	<i>Placopsilina</i> d'Orbigny, 1850 .. <i>Placopsilinella</i> Earland, 1934 .. <i>Bellonina</i> Carter, 1877 .. <i>Diffusilina</i> Heron-Allen and Earland, 1924 ..	Recent Recent Recent Recent
	Polyphragminae	<i>Haldonia</i> Chapman, 1898 .. <i>Polyphragma</i> Reuss, 1871 .. <i>Stylobina</i> Karrer, 1877 .. <i>Stacheia</i> Brady, 1876 ..	Recent Cretaceous Miocene Carboniferous—Jurassic
Fam. XXVII.— LOFTUSIIDAE	..	<i>Loftusia</i> Brady, 1869 ..	Upper Cretaceous
Fam. XXVIII.— REOPHACIDAE	Nodosinellinae ..	<i>Nodosinella</i> Brady, 1876 .. <i>Succaminopsis</i> Sollas, 1921 ..	Carboniferous — Cretaceous Ordovician — Carboniferous
	Reophacinae ..	<i>Reophax</i> Montfort, 1808 .. <i>Sulcophax</i> Rhumbler, 1931 .. <i>Hormosina</i> Brady, 1879 .. <i>Haplostiche</i> Reuss, 1861 ..	Cambrian—Recent Recent Jurassic—Recent Carboniferous (?), Jurassic—Recent
	Aschemonellinae	<i>Kalamopsis</i> de Folin, 1883 .. <i>Turriculavina</i> Rhumbler, 1911 .. <i>Nodelium</i> Rhumbler, 1913 ..	Recent Recent Cretaceous—Recent
	Sphaerulininae	<i>Aschemonella</i> Brady, 1879 .. <i>Sphaerulina</i> Cushman, 1910 .. <i>Ammosphaerulina</i> Cushman, 1912 ..	Cretaceous—Recent Recent Recent
Fam. XXIX.— TEXTULARIIDAE	..	<i>Spiroplectammina</i> Cushman, 1927 .. <i>Ammospirata</i> Cushman, 1933 .. <i>Annabuculoides</i> Plummer, 1932 .. <i>Textularia</i> DeFrance, 1824 .. <i>Textularioides</i> Cushman, 1911 .. <i>Bigneriina</i> d'Orbigny, 1826 .. <i>Volutina</i> d'Orbigny, 1826 .. <i>Deckerella</i> Cushman and Waters, 1928 .. <i>Cribrostomum</i> Möller, 1879 .. <i>Olimacamina</i> Brady, 1873 .. <i>Monogenerina</i> Spandel, 1901 .. <i>Cribrogenerina</i> Schubert, 1907 ..	Upper Carboniferous—Recent Lower Oligocene—Recent Upper Cretaceous Cambrian—Recent Recent Upper Carboniferous—Recent Eocene—Recent Upper Carboniferous Carboniferous—Permian Carboniferous—Permian Permian Carboniferous—Permian
Fam. XXX.— TROCHAMMINIDAE	Trochammininae	<i>Trochammina</i> Parker and Jones, 1859 .. <i>Rotaliampina</i> Cushman, 1924 .. <i>Ammocibicides</i> Earland, 1934 .. <i>Entzia</i> Daday, 1883 .. <i>Carterina</i> Brady, 1884 .. <i>Globotextularia</i> Elmer and Fickert, 1899 .. <i>Mooreella</i> Cushman and Waters, 1928 .. <i>Ammosphaeroidina</i> Cushman, 1910 .. <i>Cystammina</i> Neumayr, 1889 .. <i>Nouria</i> Heron-Allen and Earland, 1914 ..	Carboniferous—Recent Recent Eocene; Recent Recent, salt pools of Hungary Recent Recent Upper Carboniferous Recent Recent Eocene; Recent

## Super-family AMMODISCOIDEA—continued.

Family.	Sub-family.	Genus.	Time-range.
Fam. XXXI.— VALVULINIDAE	Tetrataxinae ..	<i>Globivalvulina</i> Schubert, 1920 ..	Carboniferous—Permian
		<i>Tetrataxis</i> Ehrenberg, 1843 ..	Carboniferous—Permian
		<i>Polytaxis</i> Cushman and Waters, 1928 ..	Carboniferous
	Valvulininae ..	<i>Ruditaxis</i> Schubert, 1920 ..	Carboniferous—Permian
		<i>Valvulinella</i> Schubert, 1907 ..	Carboniferous
		<i>Valvulina</i> d'Orbigny, 1826 ..	Jurassic—Recent
		<i>Clarulina</i> d'Orbigny, 1826 ..	Cretaceous—Recent
		<i>Cribrobulimina</i> Cushman, 1927 ..	Tertiary—Recent
		<i>Arenobulimina</i> Cushman, 1927 ..	Cretaceous—Recent
		<i>Eggerella</i> Cushman, 1933 ..	Cretaceous—Recent
		<i>Chrysobulimina</i> d'Orbigny, 1839 ..	Cretaceous
		<i>Marssonella</i> Cushman, 1933 ..	Cretaceous—Recent
		<i>Dorothia</i> Plummer, 1931 ..	Cretaceous—Recent
		<i>Plectina</i> Marsson, 1878 ..	Cretaceous—Recent
		<i>Goesella</i> Cushman, 1933 ..	Recent
		<i>Martinotiella</i> Cushman, 1933 ..	Upper Cretaceous—Recent
		<i>Valvulinamina</i> Cushman, 1933 ..	Eocene
		<i>Karrerella</i> Cushman, 1933 ..	Eocene—Recent
		<i>Listerella</i> Cushman, 1933 ..	Eocene—Recent
		<i>Tectulariella</i> Cushman, 1927 ..	Cretaceous—Recent
		<i>Cuneolina</i> d'Orbigny, 1839 ..	Cretaceous—Recent
		<i>Dicetina</i> Munder-Chalmas, 1887 ..	Upper Cretaceous
		<i>Lichusella</i> Cushman, 1933 ..	Eocene—Recent
		<i>Trilaxina</i> Cushman, 1911 ..	Eocene—Recent
		<i>Hagenovella</i> Cushman, 1933 ..	Cretaceous
		<i>Ataxophragmium</i> Reuss, 1861 ..	Cretaceous
		<i>Pernerina</i> Cushman, 1933 ..	Cretaceous
		<i>Lituanella</i> Schlumberger, 1905 ..	Middle Eocene
		<i>Coskinolina</i> Stache, 1875 ..	Middle Eocene
		<i>Dictyoconus</i> Blanckenhorn, 1900 ..	Middle Eocene
		<i>Gunderia</i> Cushman and Ponton, 1933 ..	Middle Eocene
	Orbitolininae ..	<i>Orbitolina</i> d'Orbigny, 1850 ..	Cretaceous
Fam. XXXII.— VERNEULINIDAE	.. ..	<i>Verneulina</i> d'Orbigny, 1840 ..	Jurassic—Recent
		<i>Trilaxia</i> Reuss, 1860 ..	Jurassic (?); Cretaceous—Recent
		<i>Gaudryina</i> d'Orbigny, 1839 ..	Jurassic—Recent
		<i>Heterostomella</i> Reuss, 1865 ..	Cretaceous—Recent
		<i>Spiroplectinella</i> Cushman, 1927 ..	Cretaceous
Fam. XXXIII.— FUSULINIDAE	Fusulininae ..	<i>Staffella</i> Ozawa, 1925 ..	Upper Carboniferous—Permian
		<i>Schubertella</i> Staff and Wedekind, 1910 ..	Upper Carboniferous—Permian
		<i>Fusulinella</i> Möller, 1877 ..	Lower Pennsylvanian of America; Moscovian of Eurasia
		<i>Wedekindellina</i> Dunbar and Henbest, 1933 ..	Lower Pennsylvanian of America
		<i>Fusulina</i> Fischer de Waldheim, 1829 ..	Lower to Middle Pennsylvanian of America; Moscovian of Russia and Eastern Asia
		<i>Fusiella</i> Lee and Chen, 1930 ..	Moscovian of China; Lower Pennsylvanian of Texas
	Schwagerininae	<i>Triticites</i> Girty, 1904 ..	Middle Pennsylvanian to Early Permian
		<i>Schwagerina</i> Möller, 1877 ..	Early Permian
		<i>Pseudofusulina</i> Dunbar and Skinner, 1931 ..	Uppermost Pennsylvanian (?); Early Permian
		<i>Palaeofusulina</i> Deprat, 1912 ..	Early Permian
		<i>Parafusulina</i> Dunbar and Skinner, 1931 ..	Early and Middle Permian
		<i>Polydiexodina</i> Dunbar and Skinner, 1931 ..	Middle and Upper Permian
	Verbeekinae ..	<i>Verbeekina</i> Staff, 1909 ..	Permian
		<i>Doliolina</i> Schellwien, 1902 ..	Permian
		<i>Pseudodoliolina</i> Yabe and Hanzawa, 1932 ..	Permian
	Neoschwagerininae	<i>Cancellina</i> Hayden, 1910 ..	Permian
		<i>Neoschwagerina</i> Yabe, 1903 ..	Permian
		<i>Yabeina</i> Deprat, 1914 ..	Permian
		<i>Sumatrana</i> Voiz, 1904 ..	Permian

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#### ERRATUM.

In Part I., Art. VIII., p. 74, the plates were inadvertently reversed. The explanation should therefore read Fig. 1 as given, Fig. 3 is on the top left, and Fig. 2 on the top right.

[PROC. ROY. SOC. VICTORIA, 49 (N.S.), Pt. II., 1937.]

ART. XI.—*A Note on the Occurrence of Didymograptus protobifidus* Elles in the Lower Ordovician of Victoria.

By ELIZABETH A. RIPPER, M.Sc., Ph. D.

[Read 10th September, 1936; issued separately 19th July, 1937.]

### Contents.

INTRODUCTION AND ACKNOWLEDGMENTS.

DESCRIPTION OF THE SPECIES.

EVOLUTIONAL CHANGES IN *D. protobifidus*.

REMARKS ON ASSEMBLAGES AND CORRELATIONS.

SUMMARY AND CONCLUSIONS.

### Introduction and Acknowledgments.

The pendent *Didymograpti* form a small element in the Victorian Lower Ordovician graptolite faunas. They occupy a position in the succession between the beds characterized by a great development and abundance of *Tetragraptus fruticosus* (Hall) (Bendigonian) and those which show the beginning of the rise of *Isograptus gibberulus* (Nicholson), which is found in many forms in the Castlemainian and Darriwilian. This refers particularly to the most abundant pendent form which occurs in the uppermost zone of the Bendigonian and more abundantly in the lowermost zone of the Castlemainian, and which has usually been referred to *Didymograptus bifidus* (J. Hall). Another species (*D. dependulus* Harris and Keble) occurs in the Middle Castlemainian, and is obviously descended from *T. fruticosus*, though along a different line from that which produced the *D. bifidus*-like form.

The publication of a note by G. L. Elles in "The Geology of the Whitehaven District" (Mem. Geol. Surv. Gt. Britain, 1931) on her proposed new species, *Didymograptus protobifidus*, and the subsequent publication, in 1933, of a complete description of this species make it necessary to reconsider T. S. Hall's identification (1914) of the Victorian form with *D. bifidus* (J. Hall). The species has since been identified, and referred to in Victorian lists and tables as *D. protobifidus* Elles (Harris, 1935; Thomas, 1935).

For the loan of the Victorian material on which this note is based, and which was taken to Cambridge in 1933 for examination during research under the supervision of Dr. G. L. Elles, of Newnham College, I am indebted to the Director of the Geological

Survey of Victoria (Mr. W. Baragwanath), who placed the collections in the Geological Survey Museum at my disposal, and to Dr. W. J. Harris, who allowed me the use of specimens in his private collection. In addition, I wish to thank Dr. Harris and Mr. D. E. Thomas for allowing me to use their unpublished notes on this species. Professor W. N. Benson, of the University of Otago, New Zealand, gave me much information about the graptolite assemblages in New Zealand, often from work which was at the time unpublished, and the references to examples of *D. protobifidus* occurring in New Zealand are based on an examination of his specimens. I wish also to thank the Curator of the Geological Survey Museum (Mr. W. S. Abraham) for his invaluable assistance in the forwarding of Victorian specimens to Cambridge during the progress of the work.

### Description of the Species.

#### DIDYMOGRAPTUS PROTOBIFIDUS Elles.

(Text-fig. 1.)

1933. *Didymograptus protobifidus* Elles, Summary of Progress of the Geological Survey, 1932—Part II., p. 98, text-figs. 1-3.

Rhabdosome of variable size, but usually small. Stipes pendent, usually diverging at a small angle; maximum length 3.5 cm., breadth near origin 0.4–0.7 mm., increasing gradually towards the distal end to a maximum of 1.7 mm. Sicula conspicuous. Thecae 12–14 in 10 mm., 2–3 times as long as wide, free for  $\frac{1}{3}$  to  $\frac{1}{2}$  of length, inclined at 20°–50° to the axis of the stipe.

The sicula is long and slender, and  $thl^1$  appears to originate at a point a short distance above its aperture. Details of the crossing canal and the origin of  $thl^2$  are not observable. The stipes diverge initially at about 90°, but soon curve so that they include a much smaller angle, which however is very variable and depends largely on the mode of preservation. In average-specimens the stipes are inclined in their distal parts at about 25°. The thecae are tubular and inclined usually at low angles to the axis of the stipe. Their apertural margins are straight, and may be oblique or normal to the general direction of the stipe, varying with the amount and direction of the compression undergone by the specimen. The ventral walls are straight, so that the theca retains the simple Dichograptid form.

T. S. Hall (1914), in describing some new or little known species of Victorian graptolites, refers under the name of *Didymograptus bifidus* (J. Hall) to some forms which undoubtedly belong to this more primitive species. He describes the rhabdosome as having stipes up to 3 cm. in length slightly increasing in width for the greater part of their length; thecae

11–12 in 10 mm., inclined at from 30° to 50°, four times as long as wide, free for nearly half their length, with apertures normal to the axis of the stipe, concave, with slightly mucronate denticle. The figured specimen is from Wattle Gully, Castlemaine, and shows more considerable widening of the stipes than is usually met with. As shown by G. L. Elles, the true *D. bifidus* of J. Hall, with which this species has in Victoria been compared, is usually larger, having stipes from 2 to 4 cm. in length, which reach a maximum width of 3 mm. The thecae are long and tubular, 3–4 times as long as wide, 13–15 in 10 mm., inclined at 45° and free for  $\frac{1}{4}$  of their length. The North American examples of *D. bifidus* (from Levis, Quebec, described by J. Hall, 1865, and from Deep Kill, New York, described by Ruedemann, 1904) show similar differences from the Victorian form (see table, p. 156). Text-figures 8A–D, of *D. protobifidus* Elles, and 9A, B, of *D. bifidus* (Hall), from various British localities, are added for comparison with Victorian forms.

Some examples from the Lower Castlemainian (C5) of Coal Island, Preservation Inlet, South-Western New Zealand closely resemble certain Victorian forms. They are very narrow at the proximal end, the stipes increase in breadth rather slowly, particularly after the first 7–10 thecae, and the overlap of the thecae is never much more than  $\frac{1}{2}$ , and considerably less than this at the proximal end. Some other specimens from the C5 beds of Cape Providence are small, rather primitive forms; the stipes are narrow, and increase very slowly in breadth, and the overlap of the thecae is never more than  $\frac{1}{2}$ . A single Bendigonian example was very badly preserved. The stipes appeared to be thicker than those of the C5 specimens, but the overlap of the thecae was very little and the stipes remained of practically uniform breadth. Some specimens from Nelson in the collection of the University of Otago, probably from the Golden Ridge Mine, North-Western Nelson, are to be regarded as *protobifidus-bifidus* transients. They show considerable widening of the stipes, and the overlap of the thecae increases from something less than  $\frac{1}{3}$  to  $\frac{2}{3}$  at the distal end of the stipe. These are probably on a higher horizon than the Coal Island and Cape Providence forms, and approach more closely some Victorian transients.

It will be seen from the description and figures that *D. protobifidus*, as is noted by G. L. Elles, has many of the characters seen in the proximal end of the true *D. bifidus*, so that further development along the lines of increased overlap and angle of inclination of the thecae should give a series of transients between these two forms, differing from the more primitive *D. protobifidus* in increased size of the rhabdosome and breadth of stipe. Dr. Elles notes (footnote, p. 99, 1933), the occurrence of such transients in the Skiddaw Slate faunas, and

similar forms, of which details are given in the section dealing with evolutionary changes in the species, are to be found in the Victorian Lower Castlemainian assemblages.

*Horizon.*—Upper Bendigonian and Lower Castlemainian (B1 and C5).

*Localities.*—Water-race, Wattle Gully, Castlemaine; Chewton-Fryerstown road; New Mineral Springs, Daylesford—B1. Steele's Gully, Sailor's Gully, Blacksmith's Gully, Castlemaine; LL/3, LL/4, LL/5, Allot. 76, Parish of Lancefield; LL/13, Pyalong road, and Allot. 75, Parish of Lancefield; Johnson's Creek, Parish of Cornmill; Callaghan's Adit, Bullarto; Glenhope; and various localities in the Bendigo district—C5.

The measurements of Victorian forms in Table I. are taken from the material at present under consideration. They are similar to those given by T. S. Hall, but a slightly greater degree of crowding of the thecae (13 in 10 mm. instead of 11–12 in 10 mm.) is seen, and the thecal apertures are observed to be usually oblique to the axis of the stipe rather than normal to it.

TABLE I—COMPARISON OF *D. bifidus* (J. HALL) AND *D. protobifidus* ELLES.

—	<i>D. bifidus.</i>	<i>D. proto- bifidus.</i>	<i>D. proto- bifidus.</i>	<i>D. proto- bifidus.</i>	<i>D. bifidus.</i>	
Locality .. ..	Great Britain	Great Britain	Victoria	New Zealand	Deep Kill (Ruedemann), 1905	Levis (J. Hall), 1865
Thecae in 10 mm. ..	13–15	13	12–14	12–14	13–15	..
Overlap of thecae ..	$\frac{1}{2}$ distal	$\frac{1}{2}$	$\frac{1}{2}$ $\frac{3}{4}$	$\frac{1}{2}$ $\frac{3}{4}$	$\frac{1}{2}$ $\frac{3}{4}$	$\frac{3}{4}$ $\frac{1}{2}$
Angle of divergence of stipes (initial)	65°–115°	90°–115°	80°–110°	90°–100°	90°–100°	..
Angle of divergence of stipes (distal)	15°–20°	10°–35°	10°–40°	10°–30°	20°–25°	15°–20°
Width of stipes (proximal)	*8 mm.	*4–6 mm.	*4–7 mm.	*35–6 mm.	..	1.6 mm.
Width of stipes (distal)	2.6 mm.	1.5 mm.	1.7 mm.	1.6 mm.	2.4 mm.	3.1–6.2 mm.
Inclination of thecae (proximal)	30°	20°–40°	20°–45°	30°–40°	30°	..
Inclination of thecae (distal)	45°	30°–70°	35°–50°	35°–45°	45°	48°
Thecal apertures (rel. to axis of stipe)	Very oblique	Oblique	Oblique or normal	Usually oblique	Oblique	..
Maximum length of stipes	2.4 cm.	1.2 cm.	1.0 or less to 3.5 cm.	2 cm., usually smaller	2.6 cm.	..

### Evolutional Changes in *Didymograptus protobifidus*.

The characters whose variation may be taken into account are:—

- i. Rate of increase in breadth of the stipes.
- ii. Overlap of the thecae.
- iii. Size of the rhabdosome.

The changes in the first two characters may be regarded as giving evidence of the operation of a single trend, since the chief factors contributing to an increase in the breadth of the stipe are increased overlap and inclination of the thecae.



Owing to the restricted range of *D. protobifidus* in Victoria there is very little room for the marked variation that is seen in specimens from different horizons in the British Arenigian. As a general rule, the forms appearing in the sub-zones c and d (of *D. nitidus* and of *Isograptus gibberulus*) of the *extensus* zone in Great Britain are small, have stipes of almost uniform breadth, and the thecal overlap is never more than half. Passing up through the sub-zone of *I. gibberulus* and the zone of *D. hirundo*, forms approximating more and more closely to the true *D. bifidus* are seen: the rhabdosome becomes larger, the overlap of the thecae increases and the stipes are broader and show a great increase in breadth from the proximal to the distal end.

In Victoria Bendigonian examples (text figs. 1A-C) approach most closely the earliest British forms, but appear to be somewhat more robust. The rhabdosome is very small, but the broadening of the stipes is more marked. Some C5 examples from Lancefield (LL/13, LL/3) come fairly close to the Bendigonian forms in their small size and in the narrowness of their stipes. The rest of the C5 faunas show a mixture of small and large forms, the former being probably young individuals, since they are similar in all respects to the earlier stages of full-grown individuals. At Blacksmith's Gully (text-figs. 2A, 2B), Sailor's Gully, Castlemaine and Callaghan's Adit, Bullarto (text-fig. 3) the *D. protobifidus* element of the faunas is very similar, a mixture of large and small forms, the former having usually a thecal overlap of  $\frac{1}{2}$ , rarely increasing to  $\frac{2}{3}$ . The stipes increase in breadth fairly gradually, at a rate of 0.07-0.09 mm. per theca, for the first 15 thecae, so that in large examples the breadth of the stipe becomes distally almost constant. Some of these are undoubtedly early transients between *D. protobifidus* and *D. bifidus*. Still higher transients are to be found in the Steele's Gully fauna, which contains some forms with exceedingly long stipes (text-figs. 4A, 4B). Here again the breadth of the stipe becomes practically constant after th15, but the rate of increase in breadth has risen to 0.10 mm. per theca and the distal overlap is  $\frac{2}{3}$ . A couple of examples with 18 thecae in 10 mm. and stipes rather broader than usual may doubtfully be referred to *D. artus* Elles and Wood (text-fig. 5).

The most advanced form seen occurs at Glenhope (text-fig. 7), though it is associated with small forms resembling the *D. protobifidus* of the Upper Bendigonian. The stipes are broad, the thecal overlap is  $\frac{2}{3}$ , and the whole rhabdosome is taking on the appearance of that of *D. bifidus*. Some C5 examples from the Bendigo district are also rather advanced transients, notably those from 65 BO (Coll. Geol. Surv. Vic., Reg. No. 8666) and 76 BO (Coll. G.S.V., Reg. No. 9697).

To sum up, the Victorian tuning-fork graptolites of B1 and C5 belong with few exceptions to the *D. protobifidus*-*D. bifidus* group. The Bendigonian forms are nearest to *D. protobifidus*, but the Castlemainian are to be considered as rather primitive *protobifidus-bifidus* transients. Very little difference in the stage of evolution of the C5 members of the group has been observed, though it is possible that with detailed collecting, noting the relative proportions of large and small forms, and the maximum development attained at a given horizon, the evolution of *D. protobifidus* may be used for the finer subdivision of the passage beds characterized by its presence.

### Remarks on Assemblages and Correlations.

The examples of *D. protobifidus* on which the above description is based come mainly from the Lower Castlemainian (C5), and more rarely from the uppermost Bendigonian (B1). An example from the New Mineral Springs, Daylesford, is associated with the following B1 assemblage:—

*Tetragraptus fruticosus* (Hall), 3-stiped.

*T. ? amii* Lapw., Elles and Wood.

*Didymograptus extensus* (Hall).

*Phyllograptus ilicifolius* Hall.

Of the C5 assemblages the following, from Blacksmith's Gully, Castlemaine, is typical:—

*Didymograptus protobifidus* Elles.

*D. extensus* (Hall).

*D. nitidus* (Hall), and transients between these two species.

*Dichograptus* sp.

*Goniograptus geometricus* Ruedemann.

*Tetragraptus bigsbyi* (Hall).

*T. amii* Lapw., Elles and Wood, and abundant young individuals of *T. cf. serra* or *T. amii*.

In New Zealand *D. protobifidus* occurs in beds which have been correlated by Benson and Keble (1935) with the uppermost Bendigonian (B1) and Lower Castlemainian (C5) of Victoria. The B1 assemblage of Locality 13, Cape Providence West section contains, in addition to *D. protobifidus*, which is rare, the following species:—

*Didymograptus artus* Elles and Wood.

*D. extensus* (Hall).

*D. nitidus* (Hall), and transients between these two spp.

*Tetragraptus fruticosus* (Hall), 3 stiped.

*T. pygmaeus* Ruedemann.

*T. quadribrachiatus* (Hall).

*T. bigsbyi* (Hall).

*T. taraxacum* Ruedemann.

*T. serra* (Brongniart).  
*T. amii* Lapw., Elles and Wood.  
*Goniograptus crinitus* T. S. Hall.  
*G. macer* T. S. Hall.  
*Bryograptus* sp.

A typical lower C5 assemblage is that from Loc. 32, Coal Island, Preservation Inlet, which contains—

*Didymograptus protobifidus* Elles.  
*D. extensus* (Hall).  
*D. cf. gracilis* Törnquist.  
*D. cf. euodus* Lapw.  
*D. mundus* T. S. Hall.  
*D. nitidus* (Hall).  
*D. similis* (Hall).  
*Isograptus gibberulus* var. *primula* Harris (rare), and forms tending towards var. *lunata* Harris.  
*Tetragraptus amii* Lapw., Elles and Wood.  
*T. harti* T. S. Hall.  
*T. serra* (Brongniart).  
*T. bigsbyi* (Hall).  
*T. taraxacum* Ruedemann.  
*Phyllograptus angustifolius* Hall.  
*P. cf. ilicifolius* Hall.  
*P. cf. typus* Hall.  
*Diplograptus cf. inutilis* (Hall).

*D. protobifidus* is very abundant in the C5 assemblages.

On referring to other graptolitic successions it will be obvious that the primitive tuning-fork graptolite *D. protobifidus* Elles and the more advanced form *D. bifidus* (Hall) with which it has frequently been confused, are associated with very different types of faunas, and that the recognition of the Victorian forms as *D. protobifidus* and early transients between this species and *D. bifidus* has important bearings on the correlation of the Victorian Lower Ordovician graptolitic succession with those of other regions. The uppermost Bendigonian fauna is almost exclusively Dichograptid, with prevalent many-branched pendent and horizontal forms, of which *Tetragraptus fruticosus* (Hall), *T. pendens* Elles, *Goniograptus*, *Clonograptus* and *Dichograptus* are typical. More advanced forms include the reclined *Tetragrapti*, e.g., *T. serra* (Brongn), *T. bigsbyi* (Hall), scandent four-branched forms (*Phyllograptus*), and horizontal forms with two stipes, of which *Didymograptus extensus* (Hall), *D. nitidus* (Hall) and transients between these two species are the most important. The fauna of the lowermost Castlemainian is similar, but contains a higher proportion of the horizontal and pendent two-stiped forms, and reclined two-stiped forms, e.g., *Isograptus gibberulus* (Nicholson) and its varieties, are

becoming more important. *Didymograptus bifidus* (Hall), on the other hand, is associated in Great Britain and in South America (Bulman, 1931) in the zone of that name with faunas containing a high proportion of Diplograptidae, *Phyllograpti* of high zonal types, e.g., *P. typus* Hall and *P. anna* Hall, and few or no many-branched Dichograptidae. Pendent and horizontal *Didymograpti* are abundant, but these are rarely identical with those occurring at lower horizons. Assemblages resembling those of the *D. protobifidus* passage beds of Victoria and New Zealand are found in Great Britain in the *extensus* zone, and the fauna of the sub-zone c, of *D. nitidus* (Elles, 1933), in which *D. protobifidus* makes its first appearance in the British succession, is probably their equivalent in this succession. This sub-zone is characterized by an abundance of *D. nitidus* (Hall), *D. extensus* (Hall) and *nitidus-hirundo* transients: *D. uniformis* Elles and Wood, *D. simulans* Elles and Wood, *Isograptus gibberulus* (Nicholson) (rather rare), *Didymograptus nicholsoni* Lapworth, *Glyptograptus dentatus* (Brongn.), *Phyllograptus angustifolius* Hall, *P. anna* Hall and *P. ilicifolius* Hall. This sub-zone contains much the same assemblage as the C5 beds of Victoria, with the exception of *Glyptograptus dentatus*, and is similarly followed by beds with abundant *Isograptus gibberulus*, which however does not attain the development reached by Victorian forms, since it is in Britain restricted to the sub-zone of *I. gibberulus* and the zone of *Didymograptus hirundo*.

A tentative correlation of the Victorian and British Lower Ordovician graptolitic successions, based on these considerations, and using the Victorian terminology given by Harris (1935) and Thomas (1935), is suggested in Table II. The Lower Castlemainian, with the uppermost Bendigonian, is on these grounds placed on a level with the *D. nitidus* sub-zone of the British *extensus* zone on account of the presence in it of *D. protobifidus* and early transients towards *D. bifidus*, and the Castlemainian and Bendigonian are therefore condensed, if their vertical extent is compared with that given in some earlier correlations with the British succession (Harris and Keble, 1932). Harris (1933), however, suggests, in dealing with the Isograptidae of Victoria, a correlation similar in essence to that now being put forward, and Benson and Keble (1936) have proposed a similar correlation of the graptolitic successions of New Zealand and Great Britain.

The Darriwilian can safely be placed on a level with the British *hirundo* and *bifidus* zones, on account of the great increase in the proportion of Diplograptidae which, while characterizing both, is at the same time the only feature common to both. In Great Britain the tuning-fork graptolites, after their first appearance in the *nitidus* sub-zone of the *extensus* zone, steadily increase in importance until the climax is reached in the zone of *D. murchisoni*, and they are accompanied for a time by the



higher zonal extensiform *Didymograpti*, which reach their acme of development in the zone of *D. hirundo*. In Victoria, however, the pendent *Didymograpti* are poorly developed: they are practically confined to the *protobifidus* passage beds of B1 and C5, and very few of the higher transients between *D. protobifidus* and *D. bifidus* are seen. Their place is taken at a low horizon in the Castlemainian by the Isograptidae, which quickly assume a dominant position in the assemblages and give character to the graptolite faunas of the rest of the Castlemainian and most of the Darriwilian.

### Summary and Conclusions.

After a careful comparison of Victorian and British specimens, the tuning-fork graptolite occurring most abundantly in the uppermost Bendigonian and Lower Castlemainian (B1 and C5) zones in Victoria is identified with *Didymograptus protobifidus* Elles, and is fully described. Remarks on the occurrence of the species in New Zealand are added.

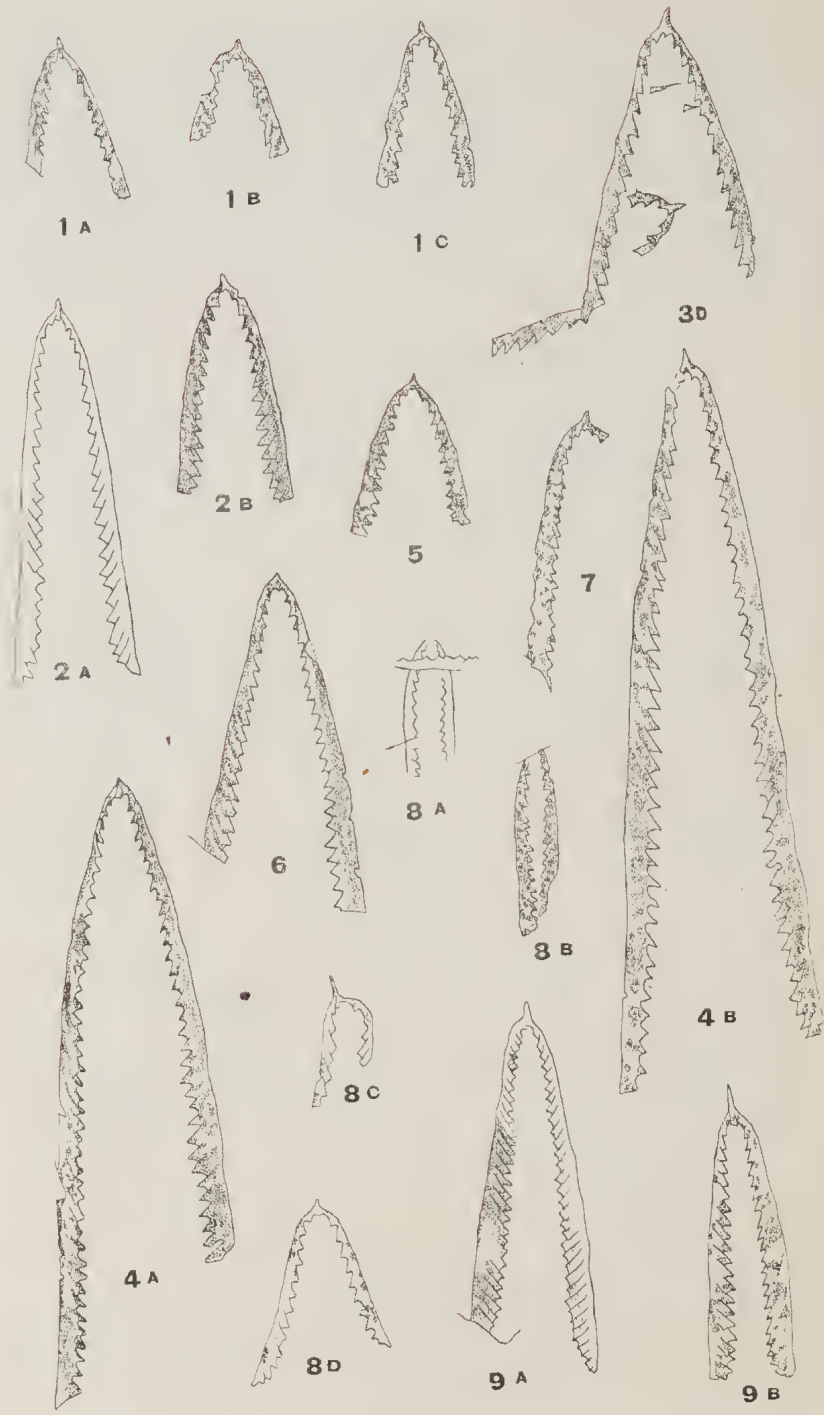
Details are given of typical assemblages with which *D. protobifidus* is associated in Victoria and New Zealand, and a comparison is drawn between these and the assemblages with which it is found in Great Britain. Further, these assemblages are contrasted with those in which *D. bifidus*, with which the Victorian form had previously been confused, is found.

From these comparisons and contrasts, it is inferred that the *protobifidus* passage beds of Victoria and New Zealand are best correlated with the sub-zone of *D. nitidus* in the *extensus* zone of Great Britain, and that the Darriwilian consequently finds its equivalent in the *hirundo* and *bifidus* zones of that succession.

TABLE II.—SHOWING THE PROPOSED CORRELATION OF THE VICTORIAN AND BRITISH LOWER ORDOVICIAN GRAPTOLITIC SUCCESSIONS.

Great Britain (Lake District). Elles, 1933.		Victoria. Thomas, 1935.	
Zone 6. <i>Didymograptus bifidus</i> ..	..	Darriwilian D2-D1 ..	Zones of <i>Diplograptus</i>
" 5. <i>D. hirundo</i> ..	..	" D5-D3 ..	Zones of Isograptidae
Zone 4. <i>D. extensus</i> —			
Subzone (d) <i>Isograptus gibberulus</i> ..	..	Castlemainian C1-C4 ..	Zones of Isograptidae
" (c) <i>Didymograptus nitidus</i> ..	..	" C5 ..	Zone of <i>Didymograptus</i>
" (b) <i>D. deflexus</i> ..	..	Bendigonian B1 ..	} <i>protobifidus</i>
" (a) Upper subzone of <i>Tetragraptus</i> (reclined)	..	" B2 ..	
		" B4-B3 ..	
			Zone of <i>Tetragraptus fruticosus</i>
Zone 3. <i>Dichograptus</i> —			
Lower subzone of <i>Tetragraptus</i> (horizontal)	..	Bendigonian B5 ..	} Zone of <i>T. approximatus</i>
		Lancefieldian L1 ..	
Zone 2. <i>Bryograptus kjerulfi</i> ..	..	" L2 ..	} Zone of <i>Bryograptus victoricae</i>
		" L3 ..	
		" L4 ..	} Zone of <i>Staurograptus dif-</i>
Zone 1. <i>Dictyonema sociale</i> ..	..	..	fissus [No equivalent]





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### Explanation of Figures.

All figures  $\times 2$  approx.

- 1A. *Didymograptus protobifidus* Elles. Example from water-race near Wattle Gully, Castlemaine. Coll. Geol. Surv. Victoria, Reg. No. 34304. B1.
- 1B. Same species. New Mineral Springs, Daylesford. Coll. Geol. Surv. Victoria, Reg. No. 4849. B1.
- 1C. Same species. Between Chewton and Fryerstown. W. J. Harris Collection. B1.
- 2A. Same species. South of Blacksmith's Gully, Castlemaine. W. J. Harris Collection. C5. A large example showing constant increase in the breadth of the stipes.
- 2B. Same species and locality. W. J. Harris Collection. A broader example.
3. Same species. Callaghan's Adit, Bullarto. Coll. Geol. Surv. Victoria, Reg. No. 33966. C5.
- 4A. *D. protobifidus*—*bifidus* transient. Steele's Gully, S. of railway line between Chewton and Castlemaine. Loc. SG/4. W. J. Harris Collection. C5. A large example.
- 4B. Same form. Steele's Gully, Loc. SG/5. W. J. Harris Collection. C5.
5. A small form perhaps referable to *D. artus* Elles and Wood. Steele's Gully. Coll. Geol. Surv. Victoria, Reg. No. 33999. C5.
6. *D. protobifidus*—*bifidus* transient. Steele's Gully. Coll. Geol. Surv. Victoria, Reg. No. 34025. C5.

7. *D. protobifidus*—*bifidus* transient. Loc. 1, Glenhope. Coll. Geol. Surv. Victoria, Reg. No. 39177. C5. An advanced form approaching *D. bifidus*.
- 8A. *D. protobifidus*. Mosedale Beck, near Troutbeck, Cumberland. From specimen in Sedgwick Museum, Cambridge (No. 220).
- 8B. Same species and locality. From specimen in Sedgwick Museum, Cambridge.
- 8C. Same species. Barf, near Keswick, Cumberland. Coll. Geol. Surv. Victoria, Reg. No. 39175. *D. extensus* zone of the Skiddaw Slates.
- 8D. Same species. Beckstones Gill, Barf, Cumberland. Coll. Geol. Surv. Victoria, Reg. No. 39176. *D. extensus* zone of the Skiddaw Slates.
- 9A. *D. bifidus* (Hall). Pont Seiont, Caernarvon, N. Wales. Zone of *D. bifidus*. From specimen in Sedgwick Museum, Cambridge (No. 19).
- 9B. Same species. Long Plantation Cutting, near Clarbiston Road, Haverfordwest, South Wales. Zone of *D. bifidus*. From a specimen in the Sedgwick Museum, Cambridge (No. 329).

[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. II., 1937.]

ART. XII.—*Tektites from the Sherbrook River District, East of Port Campbell.*

By GEORGE BAKER, B.Sc.

[Read 10th September, 1936; issued separately 19th July, 1937.]

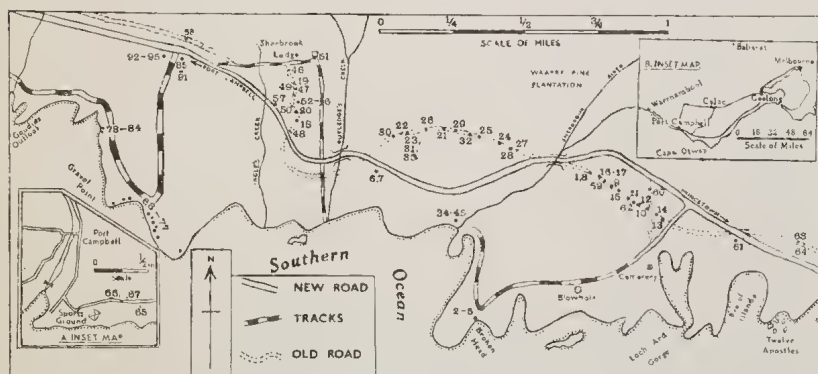
**Introduction.**

In the district east and west of the mouth of the Sherbrook River near Port Campbell, 154 miles south-west of Melbourne, careful searching of patches and old roads free from vegetation led to the discovery of those varieties of tektites called australites. Eighty-three of these interesting objects were found.

The discoveries were made over an area 4 miles long and three-quarters of a mile wide, between Port Campbell Sports Ground (inset map A) and the Twelve Apostles. No forms were located west of Port Campbell.

The position where each form was found is indicated by a number on the accompanying map. Round forms were twice as abundant as elongate forms, and all the common shapes assumed by australites were represented.

It appears that this district is within the centre of one of the more congested australite areas.



MAP 1.—Map of Sherbrook River area, showing location of australites.  
658.—2

### **Mode of Occurrence.**

The bedrock of the area consists of Tertiary limestones covered with a thin layer of clays and sands containing buckshot gravel.

Many of the australites rested loosely on the hard sandy soil of "borrow pits" which are bare patches from which material has been stripped by the Country Roads Board for surfacing the new road. Others rested on the compact earth forming the old road surface. Two forms, Nos. 18 and 20, rested on Tertiary limestone fragments used in repairing the old road, and one, No. 57, was found on the bank of the new road south-west of Sherbrook Lodge.

Of the total number of australites discovered, 58 had the anterior surface exposed, ten flange fragments and five complete forms had the posterior surface upwards, and the remainder (fragmentary) had fracture surfaces exposed to view.

Dr. Fenner (3, p. 60) has shown that the front or anterior surface of an australite is that surface showing flow-ridges. Since the majority of the forms, except flanges, occurred in the Port Campbell district with this surface upwards (reverse to flight position), each must have turned over after striking the earth, exposing the anterior surface, and thus indicating the more stable position of rest of these objects.

### **Age.**

Dr. Fenner (4, p. 140) believes that australites fell to the earth as one meteorite shower in prehistoric, but geologically recent times, and Beyer (1) states that Australian occurrences are the most recent tektites that have fallen on the earth.

Australites from Port Campbell are similar in form to those from other localities. They are fresher in appearance than the 556 forms in the Melbourne University collection, and show little or no signs of weathering, original surfaces having a somewhat duller lustre than the vitreous lustre of freshly fractured surfaces.

In this district, the old road was constructed in 1879, and the new road in 1933. Thirty-eight australites were found on the surface of the old road, and twenty on the surface of borrow-pits formed during the construction of the new road. Such occurrences point to the possibility of a fall of australites having occurred during man's occupation of the area. The general belief at present, however, is that all australites are prehistoric in age. If such be the case, those forms at Port Campbell which occur on recently prepared structures, should have fallen in prehistoric times, and it is difficult to explain their position if they fell prior to the making of roads and borrow-pits.



Dr. Fenner (3, p. 64) states that "the facts of the distribution in this area (i.e., Nullarbor Plains) strongly uphold the belief held by Australian investigators that, for the most part, the australites have been found in the positions in which they originally fell." and he gives as exceptions, accumulations in tin drifts and alluvial gravels. Under these circumstances therefore, the Port Campbell australites can be considered to have fallen on recent artificial structures, in which case, the evidence available may add some support to the possibility of the "Continuing Fall Theory" (4, p. 138) being correct.

On the other hand, there are no records of the discovery of australites in towns within the australite "strewn field." If australites are still falling, it is difficult to see why they should all be of similar composition, possess a limited variety of shapes unrepresented elsewhere in the world, and be confined in their distribution on the earth's surface, often in localized centres, to Southern Australia.

### **Descriptions of Australites.**

The colour, physical and optical properties of australites have been dealt with by many writers, and those of the Port Campbell forms do not differ in any marked degree from the descriptions already given.

The total weight of the 83 specimens is 194.056 grams, and the average specific gravity is 2.391.

The nomenclature used in this paper is similar to that employed by Dr. Fenner (3), except that the term "flow grooves" has been introduced to indicate deeper flow line structures, "bubble craters" to indicate surface cavities deeper and larger than bubble pits, and "flow pattern" to embrace flow lines and flow grooves. Letters and figures thus :—Albi, refer to the classes and groups in the Fenner classification of the Shaw collection (3).

CLASS A—(Complete or nearly complete forms).

*Buttons.*—Seventeen specimens, average weight 3.143 grams, average specific gravity 2.397.

Specimen No. 63 is unique in having both surfaces equally honeycombed with bubble pits, and no flow lines or flow ridges.

In Nos. 5, 65, 74, 78, and 79, flow ridges are anti-clockwise, in No. 80 clockwise, and in the remainder, one to three concentric flow ridges occur on the anterior surface. In some cases, the ridges become crinkly towards the equators of the forms. Flow lines may be radial or crinkly on either posterior or anterior surfaces. Smooth equatorial bands indicate the position from which the flanges have flaked away from the body. No. 65 possesses a bubble crater 4 mm. across, and in No. 80, a pustule

contained in a bubble crater itself has a small bubble pit. Bubble pits are most common on the posterior surfaces, and they may be circular or elongated.

No. on Map.	University Collection No.	Fenner Classification.	Diameter in mm.	Depth in mm.	Width of Flange in mm.	Weight in gms.	S.G.
63	3007	A1a	20	8.5	3.5	3.547	2.396
79	2981	"	20.5	8.5	3	3.667	2.401
78	2980	"	22	10	3.5	5.368	2.408
1	2730	A1bi	23	9	5	4.670	2.426
19	2943	"	21	12	3	5.023	2.411
18	2942	A1bii	24	11	4	5.432	2.401
95	3003	"	16.5	8.5	4	2.010	2.412
66	3005	A1biii	20	10	4	4.303	2.395
46	2990	A1biiia	14	8	..	1.886	2.402
65	3004	"	15.5	9.5	..	2.437	2.361
74	2974	"	16	10.5	..	3.264	2.405
80	2986	"	15	9.5	..	2.406	2.382
5	2929	A1biiib	14	7	..	1.275	2.361
29	2953	"	11.5	7	..	1.375	2.412
72	2973	"	11.5	8	5	1.998	2.416
11	2935	A1biiic	9	6	..	0.733	2.379
24	2948	A1f	19	11	..	4.045	2.385

Total weight = 53.429 gms.

*Lenses.*—Six specimens, average weight 1.072 grams, average specific gravity 2.387.

In Nos. 52 and 85 the rim is well defined, suggesting the development of a new flange. Flow ridges are anti-clockwise in No. 30, clockwise in No. 52, and concentric in Nos. 4, 13, and 85. The number of flow ridges is never more than two, and often only one. Flow lines are sometimes radial. Bubble craters and shallow "saw-marks" are rare. Bubble pits, mainly on the posterior surface, may be circular, oval or elongated, and on the honeycombed posterior surface, smooth areas often appear which possess a complicated flow line design.

Specimen No. 93 is a flat disc which Dr. Fenner suggests should be classed amongst the lenses on account of its probable genetic relationship to lens forms. Sub-class A2f of Fenner's classification constitutes the "pitted discs" which are considered to have been derived from lens-shaped australites by erosion and abrasion. The posterior surface of No. 93 possesses twelve bubble craters, but the form would not fall into the class A2f since it is extremely fresh, with entire and original surfaces, so it is placed in a special group A2i. The form is smaller than the discoidal australite described by Professor Skeats (6, p. 365), but Fenner records a still smaller type (3, p. 69) from the Shaw collection, which weighs only 0.15 grams. Still smaller forms in the Melbourne University collection, from Mr. S. F. C. Cook of Kalgoorlie, weigh respectively 0.104, 0.105, 0.118, 0.129, and 0.145 grams. All of these, however, have suffered a certain amount of abrasion.

No. on Map.	University Collection No.	Fenner Classification.	Diameter in mm.	Depth in mm.	Weight in gms.	S.G.
52	2999	A2a	14.5	8	1.782	2.366
4	2928	A2b	12	6	1.026	2.353
30	2954	"	13	6.5	1.404	2.441
85	3014	"	13	7	1.377	2.378
13	2937	A2c	10	6	0.642	2.422
93	3000	A2i	9	1.5	0.200	2.345

Total weight = 6.431 gms.

*Ovals.*—Five specimens, average weight 3.338 grams, average specific gravity 2.403.

One form in this group was too large to be accommodated in A3b of Fenner's classification, so it has been necessary to constitute the following groups:—

A3bi—long axis over 21 mm.

A3bii—long axis 18 to 21 mm.

In Nos. 57 and 51 small remnants of flanges remain. Flow ridges are clockwise in No. 77, anti-clockwise in No. 71, and irregular in the other forms. In No. 51, flow grooves occur on the anterior surface, and around the sides of the form, depressions and ridges have been formed by flaking. In No. 57, a large flow lined area surrounded by bubble pits occurs on the posterior surface.

No. on Map.	University Collection No.	Fenner Classification.	Length in mm.	Breadth in mm.	Depth in mm.	Weight in gms.	S.G.
57	2987	A3bi	24	18	11	6.516	2.439
51	2994	A3bii	19	14.5	13	5.038	2.401
77	2975	A3c	16	13.5	9	2.533	2.395
25	2949	A3d	14	11	6	1.330	2.418
71	2976	"	13	11	6.5	1.274	2.364

Total weight = 16.691 gms.

*Boats.*—Ten specimens, average weight 6.795 grams, average specific gravity 2.397.

In sub-class A4a, it has been necessary to provide three groups in order to accommodate forms having larger dimensions than those given by Fenner:—

A4ai—long axis over 40 mm.

A4aii—long axis 30 to 40 mm.

A4aiii—long axis 20 to 30 mm.

No. 76 is the largest form in this collection, and it possesses markings somewhat similar to those present on Billitonites, which often extend across the equator of the form from the anterior to the posterior surface, where they appear as circular pits. Flow

ridges are concentric in Nos. 68, 69, 83, 86, and 22, anti-clockwise in No. 82. Flow lines are simple, elliptical, dumb-bell shaped, and rarely concentric. In No. 2, a "saw-cut" on the anterior surface passes across the equator, and becomes lateral near the edges of the posterior surface, whilst a "saw-cut" in No. 68 appears to be the continuation of a fracture face. Bubble craters in Nos. 82, 83, and 86, sometimes contain smaller pits or pustules. Bubble pits are numerous on posterior surfaces. No. 12 approaches the canoe forms in shape, but is too broad and insufficiently pointed at the ends to be classified with them.

No. on Map.	University Collection No.	Fenner Classification.	Length in mm.	Breadth in mm.	Depth in mm.	Width of Flange in mm.	Weight in gms.	S.G.
76	2970	A4ai	46	22	18	..	29.480	2.452
68	2971	A4aii	40	21	10	3	4.401	2.379
			(orig.)					
69	2972	"	34	18.5	9	3.5	3.831	2.396
			(orig.)					
81	2982	"	32	21	14	..	12.815	2.304
2	2926	A4aiii	28	14	9	..	4.271	2.384
82	2983	"	28	15	7.5	2	3.715	2.427
83	2985	"	22	14	7.5	..	2.886	2.385
86	3013	"	23	17	8.5	3	3.428	2.373
22	2946	A4b	21	11.5	7	..	2.145	2.396
12	2936	A4c	17	10	4.5	..	0.981	2.386

Total weight = 67.953 gms.

*Canoes.*—Two specimens, average weight 1.019 grams, average specific gravity 2.373:

No. 21 is "pen-nib" shaped, one end of the canoe being incomplete. Flow lines and elongated pits are parallel to the shape of the form. No. 20 is not a true canoe, but is narrower and more pointed at the ends than boat forms.

No. on Map.	University Collection No.	Fenner Classification.	Length in mm.	Breadth in mm.	Depth in mm.	Width of Flange in mm.	Weight in gms.	S.G.
21	2945	A5a	35-40	9	4	2-3	1.313	2.375
			(orig.)					
20	2944	A5c	17	8	4	..	0.726	2.372

Total weight = 2.039 gms.

*Dumb-bells.*—Three specimens, average weight 2.499 grams, average specific gravity 2.392.

No. 67 is not dumb-bell shaped in all aspects, the anterior surface possessing a strong central ridge and a bubble crater 8 mm. x 10 mm. at one end. The ends tend to be pointed. Bubble pits are rare, and flow lines follow the shape of the forms, being more conspicuous on flange remnants which are confined to the waists.

No. on Map.	University Collection No.	Fenner Classification.	Length in mm.	Width of Waist in mm.	Width of Ends in mm.	Weight in gms.	S.G.
9	2933	A6a	30	8	10	2.435	2.387
67	3006	"	30	8	9.5	3.722	2.437
3	2927	A6d	18	6.5	9	1.339	2.353

Total weight = 7.496 gms.

*Teardrop*.—One specimen, weight 3.066 grams, specific gravity 2.401.

No. 70 (2979). A7a. 20 mm. long, maximum depth 9 mm., width 13 mm. at the larger end, 6 mm. at the other end. Flange is 3 mm. wide extending from the narrow end half way along each side. Flow lines are parallel to the long axis.

CLASS B—(Fragments of forms listed in Class A).

*Button Fragments*.—Nineteen specimens, average weight 0.989 grams, average specific gravity 2.391.

The surface features of these fragments are similar to those exhibited by complete forms, but fracture faces display various flow patterns which cannot be observed in complete australites. No. 53 is a case where a button has fractured clean in half, the fracture surface exhibiting a bubble crater 7 mm. across coalesced with a smaller crater, and having an outlet on to the anterior surface. No. 55 is a portion of the other half of No. 53 showing the opposite sides of the bubble craters. No. 17 shows an internal string of bubbles arranged in crescent fashion. No. 48 is a flaked core.

No. on Map.	University Collection No.	Fenner Classification.	Width of Flange in mm.	Weight in gms.	S.G.
27	2951	B1c	3	1.054	2.406
28	2952	"	4	1.717	2.388
60	3010	B1d	4	1.408	2.416
48	2991	B1f	"	4.226	2.432
53	2995	B1i	3.5	3.440	2.389
55	2996	"	"	0.781	2.381
50	2993	B1j	4.5	1.697	2.358
58	2989	"	4	2.160	2.381
88	3016	"	4	1.950	2.422
94	3002	"	4.5	3.263	2.380
17	2941	B1k	"	0.433	2.368
54	2997	"	3.5	1.181	2.440
84	2984	"	4	0.835	2.406
91	3018	"	2.5	0.783	2.417
47	2992	B1l	"	0.863	2.397
56	2998	"	"	0.356	2.438
62	3012	"	"	0.572	2.423
87	3017	"	"	0.813	2.391
90	3019	"	"	0.450	2.356

Total weight = 26.788 gms.

*Flange Fragments*.—Twelve specimens, average weight 0.405 grams, average specific gravity 2.372.

The average width of these flange fragments is 4 mm., and attachment bands, indicating where the flanges have flaked from australites, are generally about 2.5 mm. wide.



In the Shaw collection, flange fragments were classified with nondescript fragments (3). The Port Campbell examples are included in a special group B1m, because they all appear to have been derived from round forms. Group B1m is divided into:—

B1mi—flange fragments with small portions of attached body.

B1mii—flange fragments with no trace of body.

Detached flange fragments generally have almost perfectly smooth posterior surfaces, and crinkly flow ridges on the anterior surfaces. Most of the flanges, where fractured, display complex and variable flow patterns. E. J. Dunn has figured excellent examples of such structures (2, plate 15).

No. on Map.	University Collection No.	Classification.	Width.	Weight.	S.G.
15	2939	B1mi	6	0.399	2.418
31	2955	"	5	0.265	2.409
75	2978	"	4.5	0.413	2.887
7	2931	B1mii	4	0.226	2.239
8	2932	"	4	0.529	2.340
14	2938	"	3	0.335	2.393
23	2947	"	3.5	0.242	2.372
32	2956	"	4	0.332	2.423
33	2957	"	4.5	0.275	2.330
59	3011	"	5	0.587	2.396
61	3009	"	3.5	0.454	2.377
73	2977	"	5	0.599	2.377

Total weight = 4.864 gms.

*Disc Fragment.*—Weight 0.209 grams, specific gravity 2.322.

A disc fragment is included in a special group B1n. Originally plate or disc shaped, it shows two small "saw cuts" on the posterior surface, and eight concentric flow ridges with numerous flow lines parallel to them. The thickness at the equator of the lip is 2 mm. and 1 mm. elsewhere.

*Boat Fragments.*—Three specimens, average weight 0.967 grams, average specific gravity 2.399.

Dr. Fenner has divided group B2f into:—B2fi—larger fragments, and B2fii—smaller fragments. As employed in this paper, B2fi refers to one-half or over, and B2fii to less than one-half of boat forms.

No. on Map.	University Collection No.	Classification.	Width in mm.	Depth in mm.	Weight in gms.	S.G.
64	3008	B2fi	13	7	1.397	2.408
26	2950	B2fii	13	10	0.709	2.411
89	3015	"	14.5	9	0.811	2.378

Total weight = 1.197 gms.

*Dumb-bell Fragment.*—Weight 1.538 grams, specific gravity 2.418.

No. 10 (2934). B2gi. One-half of a form which may have been "ladle-shaped." In one aspect it is similar to the "air

bomb" figured by Fenner (3, plate viii., Fig. 8). Crinkly flow ridges occur on both surfaces.

*Nondescript Fragments.*—Three specimens, average weight 0.281 grams, average specific gravity 2.369.

Bubble cavities are developed over the irregular surfaces of No. 49, and the other two fragments show intricate flow patterns.

No. on Map.	University Collection No.	Fenner Classification.	Weight.	S.G.
16	2940	B3a	0.132	2.316
49	2988	"	0.411	2.403
92	3001	"	0.301	2.388
Total weight = 0.844 gms.				

### Internal Structures.

In the accompanying sketch, some of the flow patterns observed on the fractured surfaces of australites are diagrammatically represented.

FIGS. 1-7.—Internal Structures of Australites. Fracture surfaces of various forms of australites showing flow patterns.

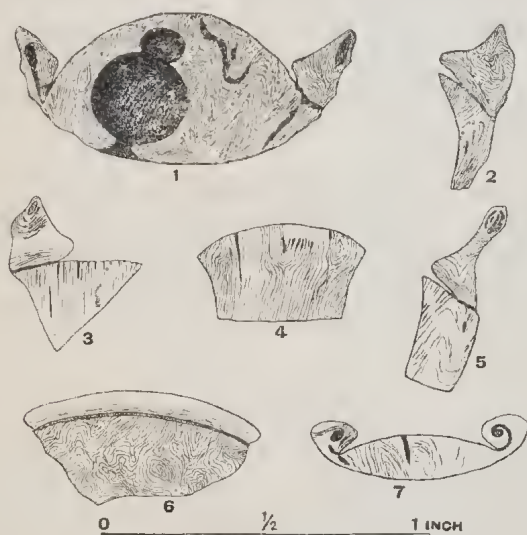


FIG. 1.—Button with flange showing large bubble cavities, flow lines and flow grooves. (2995). FIG. 2.—Button fragment showing flow lines passing into flow grooves. (2984). FIG. 3.—Button fragment showing vertical flow lines and flow grooves opening into bubble pits on the posterior surface. (3016). FIG. 4.—Boat fragment with complex flow lines and flow grooves. (3015). FIG. 5.—Button and flange fragment with elliptical flow grooves near the tip of the flange. (2951). FIG. 6.—Button fragment with flange showing small concentric flow lines, and complex flow line pattern within the body. (3002). FIG. 7.—Narrow end of teardrop with the flange showing spiral and circular flow grooves. (2979).

Bubbles are not common, a few are shown in Figs. 2 and 3. They are generally minute.

Bubble cavities are rare. A large one is illustrated in Fig. 1. It is 7 mm. across, and both it and the smaller cavity possess very smooth walls with fine flow lines.

Flange junctions can be well studied in fractured specimens. The contact with the body of the australite is often very narrow, and the line of junction is sometimes continued into the flange as flow grooves or strings of bubbles.

Flow lines are shallow, narrow markings observed on almost all flaked surfaces. They may be simple and vertical (Fig. 3), circular, elliptical, or folded in a very complex manner (Fig. 6), and in some cases, open out into flow grooves towards the posterior surface (Figs. 3 and 4). These lines appear to represent slight variations in composition.

Flow grooves are relatively deep, sometimes irregular elongated cavities, bearing a distinct relationship to flow lines with which they are usually parallel and often continuous. The grooves may be circular, spiral, elliptical, sinuous, or crescent shaped (Figs. 1, 2, 5, and 7).

No two flaked surfaces of australites from the Port Campbell district possessed similar flow patterns, the structure lines exhibiting considerable diversity, especially in the case of the flanges.

### **Composition.**

The australites from this district have not been analysed, but Dr. Summers has quoted an analysis of an australite from Curdie's Inlet (7), which is situated only 14 miles to the west of this area. It is probable that the Port Campbell occurrences are similar in composition.

### **Fragmentation.**

Abrasion, insolation, bush fires, etc., are considered to be the agents causing australites to shed their flanges and develop flaked equatorial zones (3, p. 68). That is to say, fragmentation is regarded as occurring after the australites have been resting on the earth's surface for some time.

Dr. Fenner (3), in dealing with lens forms, states that "the lens may be developed from the normal flanged button, having lost its flange in the course of development, and just started to develop a new one." Such a phenomenon must have occurred during flight through the air, since flanges are considered to be secondary structures produced during passage through the atmosphere. The flanges would most likely reach the earth as separate entities (usually fragmented), and so provide evidence

of "flight fragmentation." The main body of an australite may also undergo flaking during flight, giving rise to sectors of the body attached to portions of flanges. Lines of weakness that might be responsible for such fragmentation could be caused by the presence of strings of bubbles, "saw-cuts," or large internal bubble cavities.

The various phenomena exhibited by the australites from Port Campbell do not appear to have developed from weathering, etc., for the specimens are very fresh in appearance. Some have been undoubtedly fractured at the earth's surface, for the fracture face is highly glassy, more so than pieces of bottle glass picked up from various spots in the district, so that such fractures appear to be recent and suggest impact with a hard surface.

Some button fragments show a collection of bubbles at the union of flange and body, the escape of such gas bubbles through the narrow junctions, might have weakened the lines of contact, and assisted the fragmentary shedding of flanges during flight.

The presence of gases enclosed in cavities in the interior of australites may also have had some influence on the fracturing of the form during flight. No. 53 is exactly one-half of a button, the other half must have shattered into many fragments, most likely during flight, for only one small portion (No. 55) of the shattered half could be found in the vicinity.

The "saw-cut" in No. 82, extends from the equator of the flange to half way within the body. If such saw-cuts are due, as they may be, to contraction near the completion of flight, the continuation of development of the saw-cut would eventually lead to the breaking up of the australite into two pieces, as is thought to have been the case with specimen No. 68.

Similarly, where small saw-cuts develop through flanges and pass into the body as incipient fracture lines along the junction of the two (as in No. 79), a line of weakness would develop along which the first section of the flange would break away, either free from attached body fragment, or carrying a section of the body with it.

Apart from specimens 53 and 55, none of the fragmentary forms found in the Port Campbell area could be assigned to any other fragments, and it is therefore likely that these broken objects fell independently of one another.

In classifying 1927 fragments from the Nullarbor Plains, Dr. Fenner states that no two parts belonged to the one australite, and he suggests that the specimens were probably fractured by grass or scrub fires passing over the country on which they lay. If such was the case, one would expect to find amongst such a large number of fragments, a few at least that fitted the forms undergoing fracturing.

The evidence set out above suggests that flaking and fragmentation of australites are not necessarily due to agents acting upon them at the earth's surface, and that fragmentation might reasonably have taken place during flight.

H. H. Nininger (5) describes flight markings on stony meteorites as deformations attributable to conflict with the atmosphere during flight. Similar phenomena in australites are most likely caused in the same way, by the carving action of the resisting air on bodies travelling at high velocities.

### Summary.

Eighty-three australites, complete and fragmentary, discovered in the Port Campbell district, have been described, and their positions marked on a map. They have been classified according to Dr. Fenner's arrangement of the W. H. C. Shaw collection, with the addition of groups where necessary.

Internal structures exhibited on the flaked surfaces of australites have been figured, and suggestions put forward regarding the possible fragmentation of australite bodies during flight.

The evidence of the age of australites in the Port Campbell district suggests that they are historically recent, although convincing proof to this end is not available.

### Acknowledgments.

Thanks are due to Dr. Fenner for supplying many valuable suggestions. Miss M. K. Chisholm collected and presented specimens 11, 15, 21, 26, and 29, and R. E. Jacobson, M.Sc., discovered Nos. 47, 49, 57, 58, 60, 61, 65, 66, 85, and 92-4.

### Addendum.

Since the foregoing was written, 52 additional australites have been found by the author in the Sherbrook River district, seven months after the discoveries described in this paper. Of this number, 29 were found on the surface of areas which had previously been thoroughly searched, and 23 on the surface of places which, hitherto, had received but slight attention. One specimen in particular, a perfect australite button, has an exceedingly new and fresh appearance.

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[PROC. ROY. SOC. VICTORIA, 49 (N.S.), Pt. II., 1937.]

ART. XIII.—*The Stromatoporoids of the Lilydale Limestone.*

*Part II.*—*Syringostroma, Stromatopora, and other Genera.*

By ELIZABETH A. RIPPER, M.Sc., Ph.D.

[Read 12th November, 1936; issued separately 19th July, 1937.]

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*S. bücheliensis* (Bargatzky).  
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SUMMARY AND CONCLUSIONS.

### Introduction and Acknowledgments.

This paper contains the results of further work carried out in the Department of Geology, University of Melbourne, and in the Sedgwick Museum, Cambridge, on material from Mitchell's Quarry, Cave Hill, Lilydale, derived mainly from the collection of the National Museum, Melbourne, and is a sequel to a previous paper (Ripper, 1933) which dealt with the genera *Actinostroma* and *Clathrodictyon*.

I wish to thank the Director of the National Museum, Melbourne (Mr. D. J. Mahony), for allowing me the continued use of slides and specimens in the collections of that museum; I am indebted to the Keeper of the Department of Geology, British Museum of Natural History (Dr. W. D. Lang) for permission to examine the Nicholson Collection of stromatoporoids, and to Dr. H. Dighton Thomas, of that museum, for much helpful discussion.

### Description of Species.

Fam. STROMATOPORIDAE Nicholson.

1886. *Stromatoporidae*, Nicholson Mon. Brit. Strom., Gen. Introd., p. 90.

Coenosteum of variable form, often with basal epitheca; built up of radial pillars and horizontal laminae which may be more or less extensively combined to form a reticulate skeletal mesh. Skeletal fibre thick, minutely porous or tubulated; coenosteum not traversed by tabulate axial canals.

Genera: *Syringostroma* Nicholson.

*Stromatopora* Goldfuss.

*Stromatoporella* Nicholson.

*Parallelopora* Nicholson.

*Hermatastroma* Nicholson.

### *Syringostroma* Nicholson.

1875. *Syringostroma*, Nicholson, Rept. Geol. Surv. Ohio, ii. (2), p. 251.

Stromatoporoids in which the coenosteum is built up of distinct, stout, radial pillars, often of great length and constancy of direction, and thinner horizontal laminae; skeletal fibre minutely porous, being composed of extremely fine strands, arranged in a mesh which varies with the species.

Genotype: *S. densa* Nicholson, Rept. Geol. Surv. Ohio, vol. II., pt. ii., p. 251; pl. 24, figs. 2, 2A, 2B, 1875. *S. densum* Nicholson, Ann. Mag. Nat. Hist., ser. 6, vii., p. 326, pl. X, figs. 8, 9, 1891. Corniferous Limestone, Ohio. Selected by Nicholson, Mon. Brit. Strom., Gen. Introd., pp. 97, 98, 1886.

Bassler (1915, p. 1254) states that *S. columnare* Nicholson is the genotype of this genus, but in view of the selection in clear terms of *S. densum* by Nicholson in his diagnosis of the genus, Bassler's selection must be regarded as invalid.

This genus combines the features of *Stromatopora* and *Actinostroma*, and its species form a complete series, first recognized by Parks, passing by a thickening of the horizontal laminae from forms in which the horizontal and vertical skeletal elements are well differentiated to those in which the skeletal mesh is reticulate, and finally, by imperceptible degrees, into certain allied forms of *Stromatopora* in which the horizontal and vertical elements are equally developed (Parks, 1909).

SYRINGOSTROMA aff. NIAGARENSE Parks.

(Text-fig. 1.)

1908. *Syringostroma niagarense* Parks, Univ. Toronto Studies, Geol. Series, 5, p. 52, pl. 10, figs. 1, 2, 5, 7.

Coenosteum apparently massive, occurring only as fragments; composed of stout flexuous radial pillars, 4-5 in 1 mm., and fine horizontal laminae, usually 9-10 in 1 mm., but varying slightly in the degree of crowding.

Vertical sections of this form are easily recognizable on account of the marked difference in thickness between the horizontal and vertical skeletal elements, and are further characterized by the thick, regular radial pillars, which traverse many laminae and only disappear when slight undulations cause them to leave the plane of the section. The pillars are usually 0.2 mm. in diameter and appear to expand somewhat when crossing the laminae. The latter are extremely thin and straight, so that vertical sections show a very regular structure. Owing to the state of preservation of all specimens examined from Lilydale, the finer structure within the skeletal elements cannot be clearly seen, though a spongy texture can at times be observed.

In tangential sections the radial pillars form large round cross-sections, which in interlaminar spaces are isolated or rarely connected by narrow processes. When the section crosses a horizontal lamina, however, the pillars are seen to be connected by broad processes, so that a vermiculate network, with small pores 0.2 mm. or more apart, is the result. Astrorhizal systems, consisting usually of six horizontal canals, are abundant and conspicuous, their centres being 3-4 mm. apart, so that the branching horizontal canals of adjoining systems almost come in contact. The astrorhizal systems are apparently superimposed, since in some vertical sections the horizontal canals of two or three successive systems, which are separated by a variable number of laminae, turn abruptly upward. There is, however, no definite axial canal in such superimposed systems, and the course of the horizontal laminae is not appreciably disturbed, so that the outer surface of the coenosteum was probably smooth.

This form, while being very closely related to it, differs in several particulars from *S. niagarens* Parks. The skeletal mesh is somewhat finer, as in Parks' species there are only 3-4 radial pillars, and 7-10 horizontal laminae in 1 mm., and the latter, moreover, are crowded at irregular intervals, giving the appearance of latilaminae. The astrorhizae in *S. niagarens* are never superimposed. In addition the radial pillars in the Lilydale form are more intimately connected at the levels of the horizontal laminae, forming a vermiculate mesh similar to that of *Stromatopora*, so that this form shows an advance on the structure seen in *Syringostroma niagarens*. It may be considered as an early transient in the series leading, by the progressive fusion of the horizontal and vertical skeletal elements, to such a form as *Stromatopora foveolata* (Girty), appearing in the Helderbergian of North America (Parks, 1909, p. 9), since the radial pillars and horizontal laminae are still clearly distinguishable as separate skeletal elements.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale, Victoria.

Figured Specimen.—Coll. National Museum, Melbourne, Reg. No. 13784 (Pres. S. R. Mitchell, Esq., 3.12.23).

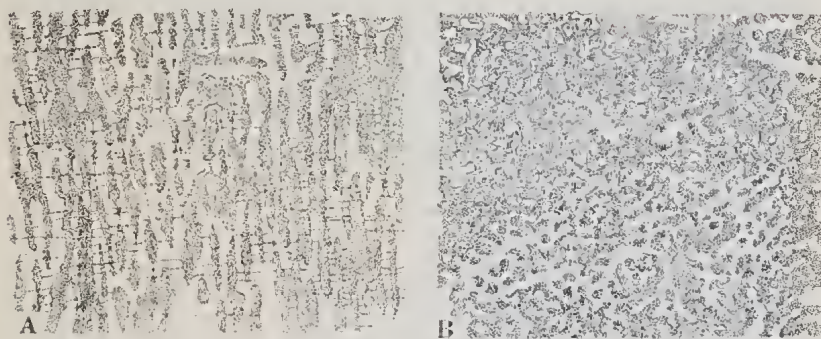


Fig. 1A. *Syringostroma* aff. *niagarensis* Parks. Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. National Museum, Melbourne, Reg. No. 13784.  $\times 9$  approx. Yeringian.

Fig. 1B. Same form. Tangential section of the same specimen.  $\times 9$  approx.

*SYRINGOSTROMA* aff. *RISTIGOUCHENSE* (Spencer).

(Pl. VIII., figs. 1, 2.)

1884. *Coenostroma ristigouchense*, Nicholson, Bull. Univ. Missouri, p. 49, pl. VI., figs. 12, 12A.

1886. *Syringostroma ristigouchense*, Nicholson, Mon. Brit. Strom., p. 97, pl. XI., figs. 11, 12.

1891. *Syringostroma ristigouchense*, Nicholson, Ann. Mag. Nat. Hist., ser. 6, vol. vii., p. 324, pl. VIII., figs. 6-8.

1909. *Syringostroma ristigouchense*, Parks, Univ. Toronto Studies, Geol. Ser., 6, p. 10, pl. 16, figs. 3-5.

Coenosteum massive, non-lamilaminar, built up of well-defined radial pillars and straight thin horizontal laminae; pillars 3-4 in 1 mm., laminae 5-6 in 1 mm. Astorhizae moderately abundant. Skeletal fibre porous.

The specimens of this form are all fragmentary, so that the form and external characters of the coenosteum cannot be observed. Vertical sections show a regular skeletal mesh made up of the sharply differentiated radial pillars and concentric laminae. The pillars are stout, reaching a diameter of 0.2 mm., straight, and pass through a considerable number of the fine laminae. These are regularly arranged, though sometimes falling into groups of two or three, but the periodic crowding characteristic of some species of *Syringostroma* rarely occurs. The pillars are usually slightly thickened at their intersections with the laminae.

In tangential sections the cut ends of the pillars appear as large rounded cross-sections which are usually isolated, or connected to form vermiculate rows in the interlaminar spaces. Where the plane of the section coincides with that of a lamina the pillars lose their identity and form a porous plate with



regularly spaced perforations, separated by distances corresponding to the diameters of the pillars. Irregularities in the mesh are frequently caused by the large and abundant astrorhizal systems, each consisting of about six radiating, branched horizontal canals. These may reach a length of 2 mm., and the systems are separated by distances (from centre to centre) varying between 3 and 5 mm. The horizontal astrorhizal canals are also discernible in vertical sections, where they appear as rounded cross-sections rather larger than the interspaces of the normal skeletal mesh.

This form is undoubtedly most closely related to *S. ristigouchense* (Spencer), but differs in some respects from that Helderbergian species. The pillars are not so thick, and are apparently isolated, while in *S. ristigouchense* they are connected by whorls of radiating fibres, which produce a characteristic mesh in tangential sections. The apparent absence of these fibres in the Victorian specimens may, however, be due to imperfect preservation. The horizontal laminae are thinner than in *S. ristigouchense* and are not so uniformly arranged in groups of two or three. These features show that the skeletal mesh of the Victorian form has not reached the degree of reticulation seen in *S. ristigouchense*. It is therefore best considered to be a transient between *S. niagarensis* Parks, which is typical of those forms in which the two skeletal elements are still distinct, and *S. ristigouchense*, in which the skeletal mesh is becoming similar to that of certain species of *Stromatopora*, e.g., *S. typica* von Rosen.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimen.—Coll. Dept. of Geology, Univ. of Melbourne, Reg. No. 1619 (piece cut from specimen in the collection of F. S. Colliver, Esq.).

#### SYRINGOSTROMA DENSUM Nicholson.

(Pl. VIII., figs. 3-5.)

- 1875. *Syringostroma densa*, Nicholson, Rept. Geol. Surv. Ohio, ii., p. 2, p. 251, pl. 24, figs. 2, 2A, 2B.
- 1886. *Syringostroma densum*, Nicholson, Mon. Brit. Strom., Gen. Introd., p. 97, pl. XI., figs. 13, 14.
- 1891. *Syringostroma densum*, Nicholson, Ann. Mag. Nat. Hist., ser. 6, vii, p. 326, pl. X., figs. 8, 9.

Coenosteum hemispherical, latilaminar; skeletal mesh dense, built up of short, slender, irregularly developed radial pillars and indefinite horizontal laminae; pillars 4-5 in 1 mm., laminae 3-4 in 1 mm., or at irregular intervals. Skeletal fibre porous astrorhizae large, abundant.

The coenosteum of the only specimen examined is hemispherical, with well-defined latilaminac, between which splitting may occur. They are between 2 and 5 mm. in thickness. Vertical

sections show an irregular reticulate skeletal mesh, in which the slender radial pillars, usually less than 0.1 mm. in diameter, are conspicuous. These are short and slightly undulating, and traverse quite short distances, often less than 1 mm. Usually at irregular intervals, but sometimes as often as 3 or 4 times in 1 mm. the pillars are united by lateral processes of similar breadth, which may coalesce to form a fairly well defined lamina. The pillars are usually cut short at their intersection with the planes of these laminae, which thus mark minor interruptions of growth within the latilaminae. These planes also determine the positions of the astrorhizal systems, the horizontal canals being seen in vertical sections as rounded cross-sections 0.2–0.3 mm. in diameter, and thus being much larger than the interspaces of the normal skeletal mesh. The canals are less frequently present on the planes of those laminae where no interruption in the formation of the pillars has taken place. The horizontal canals are frequently connected by other canals directed vertically or obliquely upwards, but the systems at various levels do not appear to be superimposed or connected in any regular manner.

In tangential sections the skeletal mesh is dominated by the cut ends of the radial pillars, which appear in the interlaminae spaces as isolated cross-sections. On the planes of the laminae they are connected by lateral processes of equal breadth, forming a fine, vermiculate network in which the porous character of the skeletal fibre is clearly shown. The astrorhizal systems are large and conspicuous, consisting of six or seven broad, much branched, radiating canals, which reach a diameter of 0.3 mm. near the centre of the system.

This form is almost identical with the original specimen from the Corniferous Limestone (Upper Helderbergian) of Ohio in the Nicholson Collection (Brit. Mus. Nat. Hist., Reg. No. P5598), though its state of preservation is rather better, but does not show the two distinct sets of pillars of different sizes which are mentioned in Nicholson's latest description of this species (Nicholson, 1891). The larger pillars are conspicuous only in some parts of the type specimen, and are not abundant. The figures given are of rather small extent, so that the true nature of the skeletal mesh is with difficulty discernible. The mesh composed of the small pillars and the indefinite horizontal laminae, and the large astrorhizal canals are characteristic of the specimen in the Nicholson Collection, and are also shown in the figures accompanying the description (Nicholson, 1891, pl. X., figs. 8 and 9).

The skeletal mesh of *S. densum* clearly shows that the species is one of the more advanced transients in the series connecting *S. niagarensis* Parks and allied forms with *Stromatopora foveolata* (Girty), *S. concentrica* Goldf., and allied forms. The radial pillars are less easily distinguishable as separate skeletal elements, and the rather indefinite laminae tend to be arranged in groups,

a number of which together form the latilaminae of the coenosteum. The mesh thus produced resembles somewhat that of such a form as *Str. foveolata*, in which, however, the pillars and laminae have still less identity and are more completely merged in a reticulate network. It is possible that *Syr. densum* is not closely related to the species of the group *Syr. niagarensis*-*Str. foveolata*, since the radial pillars are much more slender and the skeletal mesh is finer.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimen.—Coll. Dept. of Geology, Univ. of Melbourne, Reg. No. 1620, collected by A. C. Frostick, Esq.

TABLE I.—CHARACTERS OF VICTORIAN SPECIES OF *Syringostroma*, AND OF SPECIES WITH WHICH THEY ARE COMPARED.

Species.	Horizon.	Locality.	Laminae mm.	Pillars mm.	Astrorhizae.	Form of Coenosteum.
<i>Syringostroma niagarensis</i> Parks	Niagaran	N. America	4-10 thin	4-5	Abundant, branching, not super-imposed	Circular, explanate, latilaminar
<i>S. aff. niagarensis</i> Parks	Yeringian	Lilydale, V.	9-10 thin	4-5	Abundant, branching, super-imposed	Massive, non latilaminar
<i>S. ristigouchense</i> (Spencer)	L. Helderbergian	Canada	7 in 2 mm. thick	5-6 in 2 mm.	Large, branching, super-imposed	Massive, latilaminar
<i>S. aff. ristigouchense</i> (Spencer)	Yeringian	Lilydale, V.	5-6 thin, periodically crowded	3-4	Large, branching, super-imposed?	Massive, non latilaminar
<i>S. densum</i> Nich.	Yeringian U. Helderbergian	Lilydale, V. N. America	3-4 indefinite	4-5	Large, branching, not super-imposed	Hemispherical, or laminar, latilaminar

### **Stromatopora** Goldfuss, emend. Nicholson.

1826. *Stromatopora* Goldfuss, "Petrefacta Germaniae," Bd. 1., p. 21

1886. *Stromatopora* Nicholson, Mon. Brit. Strom., Gen. Introd., p. 91.

Stromatoporoids in which the coenosteum is usually massive or laminar, sometimes latilaminar; built up of a completely reticulate skeletal mesh in which the horizontal laminae and radial pillars are typically not distinguishable as separate skeletal elements. Skeletal fibre coarsely porous; astrorhizae usually abundant.

Genotype: *S. concentrica* Goldfuss, Petref. Germ., p. 22, pl. VIII., figs. 5A-C, 1826; Nicholson, Mon. Brit. Strom., p. 164, pl. III., fig. 5, pl. XI., figs. 15-18, pl. XX., fig. 10, pl. XXI., figs. 1-3, pl. XXIV., figs. 9, 10, 1886-1891.

The species of *Stromatopora* fall into two more or less distinct groups. In the first (group of *S. concentrica*), containing many Silurian and Helderbergian species, the coenosteum is

usually latilaminar, and in vertical sections horizontal laminae are clearly distinguishable, while the radial pillars are poorly developed. Such a group includes *S. foveolata* (Girty), *S. typica* von Rosen, *S. constellata* Hall, and *S. concentrica* Goldfuss, all of which seem to show a continuation of the trend of thickening of the horizontal laminae seen in the species of *Syringostroma*. The second group (group of *S. hüpschii* (Bargatzky)) contains those forms, usually common in the Middle Devonian, in which the horizontal laminae are reduced to occasional processes joining the relatively stout, straight radial pillars, which thus dominate the skeletal mesh as seen in vertical sections. Such species are *S. beuthii* Bargatzky, *S. hüpschii* (Bargatzky), *S. büchelensis* (Barg.), *S. gentilis* Gortani, and *S. lilydalensis*, sp. nov. Tangential sections of members of both groups, however, show the completely reticulate skeletal mesh characteristic of the genus.

#### STROMATOPORA FOVEOLATA (Girty).

(Text-fig 2.)

1895. *Syringostroma foveolatum*, Girty, Rep. State Mus., New York, 48, ii., p. 295, pl. VI., figs. 8, 9.

1909. *Stromatopora foveolata*, Parks, Univ. Toronto Studies, Geol. Ser. 6, p. 20, pl. 17, figs. 5-7; pl. 18, figs. 4, 10.

Coenosteum massive, external form unknown; skeletal mesh vermiculate, but with distinct horizontal laminae, 4 in 1 mm., and less conspicuous radial pillars, 4-5 in 1 mm.

The radial pillars as seen in vertical section are stout, over 0.2 mm. thick, and discontinuous, often passing through only one horizontal lamina. These are thick, being composed of 2-5 or more thin fibres which connect the radial pillars, and are crowded at irregular intervals, leaving open spaces occupied by horizontal astrorhizal canals. In tangential sections the radial pillars present much the same appearance as do those in similarly oriented sections of *Syringostroma* aff. *niagarensis* Parks, but they are even more completely united on the planes of the laminae to form a vermiculate network with very small pores, rather more than 0.2 mm. apart. In the better preserved parts of tangential sections the minutely fibrous structure of the vertical pillars can be observed; in general, however, this is not as well shown as in the examples of the species described by Parks (1909) from the Lower Helderbergian (*Pentamerus* limestone) of New York.

Astrorhizae are moderately abundant, and grouped into vertical systems with an axial canal, which passes through about four horizontal laminae. The axial canal is sometimes tabulate and is wall-less, being bounded by the radial pillars and the upturned edges of the laminae, and joined at intervals of one or two laminae by the horizontal canals, which turn abruptly upwards. The laminae are only very slightly curved, so that prominent monticules may not have been present on the upper surface.



This form is somewhat coarser in skeletal structure than the Lower Helderbergian examples described by Girty and Parkes, but there is little doubt that it should be referred to this species. Another example from Lilydale (Coll. Nat. Mus., Melbourne, Reg. No. 13764) is somewhat finer and, both in vertical and tangential sections, shows a less complete fusion of the vertical and horizontal skeletal elements, so that, while being included under this species, it should probably be regarded as an earlier transient in the series *Syringostrota-Stromatopora*. It is thus clear that in the Lilydale fauna later transients (*Str. foveolata*) occur along with surviving earlier transients (*Syr. aff. niagarensis* and *S. aff. ristigouchensis*) which are but little removed from the primitive end-member of the series (*Syr. niagarensis*) characterizing Niagaran (= Wenlock) beds in North America.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimen.—Coll. Dept. of Geology, Univ. of Melbourne, Reg. No. 768.



Fig. 2A. *Stromatopora foveolata* (Girty). Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. Depart. of Geology, University of Melbourne, Reg. No. 768.  $\times 9$  approx. Yeringian.

Fig. 2B. Same species. Tangential section of the same specimen.  $\times 9$  approx.

#### STROMATOPORA aff. HÜPSCHII (Bargatzky).

(Pl VIII., figs. 7, 8.)

1881. *Caenopora hüpschii* Bargatzky, "Die Stromatoporen des rheinischen Devons," p. 62.

1886 *Stromatopora hüpschii* Nicholson, Mon. Brit. Strom., Gen. Introd., p. 50, figs. 6A, 6B.

1891. *Stromatopora hüpschii* Nicholson, Mon. Brit. Strom., p. 176, pl. X., figs. 8, 9; pl. XXII., figs. 3-7

1919. *Stromatopora hüpschii*, Vinassa de Regny, Palaeontologia italica, xxiv., p. 113, pl. XII. (VII.), figs. 5, 6.

(For further synonymy see Nicholson, 1891.)

Coenosteum probably massive, composed of well defined, stout radial pillars (3-4 in 2 mm.) connected occasionally by horizontal processes of varying thickness.



Vertical sections show a rather coarse, open, but very regular skeletal mesh, which is dominated by the thick, straight radial pillars. These are connected both by fairly infrequent horizontal processes of a similar thickness, joining usually but two or three pillars, and by more abundant, extremely thin "tabulae," which may connect several successive pillars. These processes, however, never coalesce to form definite horizontal laminae. The skeletal fibre is very thick, having a diameter of 0.2–0.3 mm., but does not form a compact mesh, since the radial pillars are separated by distances greater than their diameters.

In tangential sections the radial pillars with their occasional connecting processes form an extremely regular, open, vermiculate mesh, in which the porous nature of the skeletal fibre is clearly seen. Astrorhizae are not present.

This stromatoporoid, while obviously very closely related to *Str. hüpschii* (Barg.), differs from that form in some respects, so that, in the absence of further material, one specimen only being at present available, it is inadvisable either to identify it definitely with the European form or to separate it as a new species. The skeletal mesh in *S. hüpschii* is rather more compact, since the radial pillars are separated by distances less than their diameter, and tangential sections are further distinguished by the abundant small astrorhizae.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimen.—Coll. National Museum, Melbourne, Reg. No. 13790 (Pres. J. S. Green, Esq., 7.8.11).

#### STROMATOPORA BÜCHELIENSIS (Bargatzky).

(Pl. VIII., figs. 9, 10.)

- 1881. *Caenopora bücheliensis* Bargatzky, "Die Stromatoporen des rheinischen Devons," p. 62.
- 1886-1891. *Stromatopora bücheliensis* Nicholson, Mon. Brit. Strom., pp. 23, 186, pl. X., figs. 5-7, pl. XXIII., figs. 6, 7.
- 1912. *Stromatopora bücheliensis* Gortani, Rivista italiana di palaeontologia, xviii., p. 125, pl. IV., figs. 12, 13.
- 1919. *Stromatopora bücheliensis* Vinassa de Regny, Palaeontographia italica, xxiv., p. 116.
- 1934. *Stromatopora bücheliensis* Le Maitre, Mém. Soc. Géol. du Nord, xii., p. 194, pl. XIV., figs. 4, 5.

Coenosteam massive, built up of undulating "laminae," which, however, are not distinguishable in thin sections as definite interruptions in the deposition of the skeletal fibre. Skeletal fibre porous; skeletal mesh reticulate; vertical pillars conspicuous, 5 or 6 in 2 mm.

These specimens are massive in habit and are built up of irregular latilaminae about 5 mm. thick. In vertical sections the radial pillars are distinguishable as separate skeletal elements,

but the laminae are rudimentary. The skeletal mesh is considerably distorted as a result of the extreme abundance of large "Caunopora" tubes. The skeletal fibre is rather thick (between 0.2 and 0.3 mm.) and the mesh is compact, since the interspaces have a similar or rather smaller diameter. These latter may sometimes be occupied by tabulae. Tangential sections show a compact, vermiculate skeletal mesh, which is sometimes interrupted by the poorly developed astrorhizae, consisting of small branching horizontal canals. They are usually not grouped into distinct systems, but occasionally small, remote groups of radiating canals, the whole group being but 2 or 3 mm. in diameter, may occur at intervals of about 10 mm.

Most specimens have abundant, large and very regularly distributed "Caunopora" tubes. These are thick-walled, about 0.5 mm. in diameter, and are usually filled with secondary calcite. They are occasionally tabulate, the tabulae being slightly convex towards the surface of the coenosteum. When branching of the "Caunopora" tube occurs, the new tube runs horizontally for a short distance before traversing the coenosteum vertically. Horizontal connecting processes also occur between two adjacent tubes, but these still have definite walls and are thus distinct from the skeletal mesh of the coenosteum.

In the distortion of the skeletal mesh, which obscures their true relationships, and the type of "Caunopora" tubes these examples resemble some placed by Nicholson in this species, and come particularly close to one example in the Nicholson Collection (Brit. Mus. Nat. Hist., Reg. No. P5913) from Gerolstein, Eifel District, Germany, in which, however, the skeletal mesh is a little finer than in the Victorian form.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimen.—Coll. National Museum, Melbourne, Reg. No. 13763.

STROMATOPORA BÜCHELIENSIS var. DIGITATA Nicholson.

(Pl. VIII., fig. 6, Text-fig. 3.)

1891. *Stromatopora bücheliensis* var. *digitata*, Nicholson, Mon. Brit. Strom., p. 187, pl. XXIII., figs. 4, 5.

In addition to the typical form, there is present in the Lilydale limestone a rarely occurring variety which is distinguished on account of its mode of growth. The coenosteum is made up of a number of cylinders which are composed of concentric laminae. The skeletal mesh is reticulate, and of the same type as that of *S. bücheliensis*, but the horizontal laminae and radial pillars are more conspicuous and distinct, each numbering about 6 in 2 mm. Astrorhizae are apparently not present.

"Caunopora" tubes are abundant, and of a peculiar type. They are regularly arranged in systems radiating from the axes of the cylinders, and are thus divergent and branch frequently, usually giving off horizontal lateral tubes which turn abruptly and traverse the cylinder in a direction normal to its surface. The tubes are thick-walled and possess funnel-shaped tabulae, which sometimes form vesicular tissue near the periphery. In tangential sections the "Caunopora" tubes resemble transverse sections of *Syringopora*, though they are of much smaller size, reaching a diameter of only 0.5 mm.

This variety resembles somewhat *S. concentrica* var. *colliculata* Nich. in the occurrence of definite horizontal laminae within the reticulate skeletal mesh. It is easily distinguished from that form by the apparent lack of astrorhizae, which, in superimposed systems, are characteristic of Nicholson's variety, and by the less regular skeletal mesh, in which the laminae are not so highly developed.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimen.—Coll. National Museum, Melbourne, Reg. No. 13794 (Pres. R. H. Annear, Esq., 12.3.14).



Fig. 3A. *Stromatopora bucheliensis* var. *digitata* Nicholson. Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. National Museum, Melbourne, Reg. No. 13794.  $\times 9$  approx. Yeringian.

Fig. 3B. Same species. Tangential section of the same specimen.  $\times 9$  approx.

STROMATOPORA LILYDALENSIS, sp. nov.

(Pl. IX., figs. 1, 2)

Form of complete coenosteum unknown, but apparently massive or digitate; built up of latilaminae about 1 cm. in thickness; surface of coenosteum probably smooth. Radial pillars conspicuous, divergent, 6 in 2 mm.; horizontal laminae not distinguishable.

In vertical sections the skeletal mesh is completely dominated by the vertical element, which forms a network of anastomosing pillars. These appear to branch, and diverge fairly regularly from vertical planes about 3 mm. apart. This structure, however, is not sufficiently pronounced to destroy the massive appearance of the coenosteum as a whole. The skeletal fibre is usually 0.2-0.3 mm. thick, but may become stouter towards the upper limits of the latilaminae, and is finely porous. The spaces between the pillars are of approximately the same diameter as the pillars, and are traversed at irregular intervals by thin fibres. As shown by Parks (1909, p. 47) these spaces are not zooidal tubes, under which name they were described by Nicholson, but the so-called tabulae represent the very much reduced horizontal skeletal element.

Tangential sections show a vermiculate skeletal mesh in which the radial pillars are indistinguishable from the connecting processes. This mesh is unusually regular, since neither astrorhizal canals nor "Caenopora" tubes are present.

Some examples in which the mesh is slightly coarser appear to be transitional between this species and *S. concentrica* Goldf. since the pillars become less divergent and the laminae more definite, and the whole coenosteum assumes a latilaminar aspect. (Coll. National Museum, Melbourne, Reg. No. 13782.)

This abundant species is most closely related to *S. bücheliensis* (Barg.), which is characteristic of the Middle Devonian of Europe. In this form the radial pillars, while being similarly spaced, usually have not the divergent arrangement which is so characteristic of the Lilydale species. One specimen (Brit. Mus. Nat. Hist., Reg. No. P5911) from the Middle Devonian of Büchel, referred to this species by Nicholson, has divergent pillars, but has also a much finer skeletal mesh, so that it is distinct from the typical form, and should probably be separated from it. The skeletal fibre of *S. bücheliensis* is somewhat finer, and the presence of astrorhizae in the European form still further distinguishes it from *S. lilydalensis*.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured syntypes.—Coll. National Museum, Melbourne, Reg. Nos. 13768 (Pres. F. Chapinan, Esq., 7.6.02), and 13785 (Pres. S. R. Mitchell, Esq., 3.12.23).

### **Stromatoporella** Nicholson.

1886. *Stromatoporella* Nicholson, Mon. Brit. Strom., p. 92.

1886. *Stromatoporella* Nicholson, Ann. Mag. Nat. Hist., ser. 5, xvii., footnote, p. 234.

1914. *Stromatoporella* Heinrich, Centralblatt f. Min., etc., xv., p. 735; 1916, Journ. Geol. xxiv., p. 60.

1936. *Stromatoporella* Parks, Univ. Toronto Studies, Geol. Ser. 39, p. 90.



Stromatoporoids in which the coenosteum is usually laminar, with a basal epitheca; composed of radial pillars and horizontal laminae which are distinguishable as separate skeletal elements; radial pillars short, generally traversing one interspace only; skeletal interspaces usually tabulate; astrorhizae abundant, well-developed and often superimposed. Skeletal fibre thick, porous.

Genotype: *Stromatopora granulata* Nicholson, Ann. Mag. Nat. Hist., ser. 4, xii., p. 94, pl. IV., figs. 3, 3A, 1873; *Stromatoporella granulata*, Nicholson, Mon. Brit. Strom., p. 202, pl. XXVI., figs. 1, 1A, 1B, 1891. Hamilton Group, Ontario.

#### STROMATOPORELLA GRANULATA Nicholson.

(Pl. IX., figs. 3-5.)

1873. *Stromatopora granulata* Nicholson, Ann. Mag. Nat. Hist., ser. 4, xii., p. 94, pl. IV., figs. 3, 3A.

1886. *Stromatoporella granulata* Nicholson, *Ibid.*, ser. 5, xviii., p. 10.

1886-1892. *Stromatoporella granulata* Nicholson, Mon. Brit. Strom., p. 202, pl. I., figs. 4, 5, 14, 15; pl. IV., fig. 6; pl. VII., figs. 5, 6; pl. XXVI., figs. 1, 1A, 1B.

1936. *Stromatoporella granulata* Parks, Univ. Toronto Studies, Geol. Ser., 39, p. 95, pl. XV., figs. 6, 7; pl. XVI., figs. 1-7.

Coenosteum massive, of small size, built up of latilaminae 2-3 mm. broad; horizontal laminae well defined, undulating, 4-6 in 1 mm., connected by stout, complete, often hollow radial pillars, 3-4 in 1 mm.; astrorhizal mamelons present.

In vertical section the skeletal mesh presents a strong resemblance to that of a *Clathrodictyon* of the type of *Cl. regulare* (von Rosen), or of *Cl. calamosum* Ripper, in which the radial pillars are obviously formed by the downward inflection of the rather thick laminae. The porous skeletal fibre and the greater thickness of the laminae, however, show that the form is in reality a *Stromatoporella*. The laminae are grouped into latilaminae, at the upper and lower boundaries of which the skeletal mesh becomes irregular and considerably finer, showing that interruptions in the growth of the coenosteum have taken place. The horizontal laminae are strongly arched between the radial pillars, and are often broken, so that these upwardly inflected parts of the laminae sometimes appear to replace the pillars. Astrorhizae are abundant, and appear in vertical section as well defined horizontal non-tabulate canals of rather greater diameter than the interlaminar spaces. Near the astrorhizal mamelons these turn vertically upward, but no axial canals have been observed.

The tangential section is characterized by the isolated radial pillars, which often appear as rings in cross-section, and by the cut edges of the laminae, which have a concentric arrangement about the astrorhizal mamelons. The astrorhizae, owing probably to the inclined courses of the canals, are not very conspicuous in tangential section.



The Victorian example is in almost every way identical with the form described by Nicholson (1891-2) from the Hamilton Group of Ontario. The upward inflection of the laminae to form perforated tubercles is much more pronounced in the Victorian specimen, the astrorhizae are probably less highly organized, and the interlaminar septa, which are moderately common in the Canadian form, are lacking. In the absence of further material, and in view of the great variations exhibited even within individual coenosteia, it is probably inadvisable to describe this form as a new variety, and it is therefore included in the species as defined by Nicholson.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimen.—Coll. Dept. of Geology, Univ. of Melbourne, Reg. No. 1622.

STROMATOPORELLA cf. DAMNIONENSIS Nicholson.

(Pl. IX., figs. 7, 8.)

1892. *Stromatoporella damnionensis* Nicholson, Mon. Brit. Strom., p. 207, pl. XXVII., figs. 8, 9.

Coenosteum massive, latilaminar, built up of conspicuous undulating horizontal laminae, of which 4 or 5, with the interlaminar spaces, occupy 1 mm., and irregularly spaced radial pillars; astrorhizal mamelons present.

Vertical sections show the regular horizontal laminae, reaching a thickness of 0.2 mm., which are thrown into undulations at intervals, forming the astrorhizal mamelons. The radial pillars are stout, traverse usually but one interlaminar space, and often appear to be formed by the downward inflection of the horizontal laminae. Interlaminar septa are rarely present. Irregularly distributed horizontal and vertical canals of approximately the same diameter as the interlaminar spaces probably belong to the astrorhizal systems.

In tangential section the skeletal mesh has the appearance characteristic of *Stromatoporella*. The radial pillars are isolated where the section passes through an interlaminar space, and are united in a vermiculate mesh or a solid plate to form the laminae. The cut edges of the upturned laminae in the vicinity of the astrorhizal mamelons are very conspicuous, though the canals are rarely discernible, and the centres of the mamelons are usually replaced by coarsely crystalline calcite.

This specimen corresponds well with *Str. damnionensis* Nich. of the Devonian limestones of South Devon, and resembles most closely the specimen from Teignmouth (Brit. Mus. Nat. Hist., Reg. No. P6042), which is that figured by Nicholson on Pl. XXVII. (Figs. 8 and 9) of the Monograph of British

Stromatoporoids, and which must be regarded as the holotype. The laminae are rather thinner and more crowded than in the British specimen, but the type of skeletal mesh, the arrangement of the astrorhizae, and the form of the coenosteum are similar in both examples. The Victorian form resembles less closely the examples of the species from Gerolstein and Sötenich in the Nicholson Collection, since these have a much coarser skeletal mesh and thicker laminae.

The species is readily distinguished from *S. granulata* Nich. by the straighter laminae and the solid radial pillars. Tangential sections of the two species are thus distinct, as the hollow radial pillars in *S. granulata* appear as circles, which are lacking in the corresponding sections of *S. damnionensis*. The group of *S. prima* Parkes (1933) may contain related forms, but their affinities have not been discussed, and no definite statements can therefore be made without an examination of specimens.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimen.—Coll. National Museum, Melbourne, Reg. No. 13788 (Pres. W. J. Parr, Esq., 7.11.13).

TABLE II.—CHARACTERS OF VICTORIAN SPECIES OF *Stromatoporella*.

Species.	Horizon.	Locality.	Laminae num.	Pillars mm.	Astrorhizae.	Form of Coenosteum.
<i>Stromatoporella granulata</i> Nich.	Hamilton Yeringian	N. America Lilydale, V.	4-6	3-4, formed by inflection of laminae	Super-imposed, situated on mamelons	Laminar or massive
<i>S. cf. damnionensis</i> Nich.	Yeringian	Lilydale, V.	4-5	Irregularly spaced, formed by inflection of laminae	Super-imposed, situated on mamelons	Laminar or massive
<i>S. damnionensis</i> Nich.	M. Devonian	Europe ..	6	Irregularly spaced	Super-imposed, situated on mamelons	Massive

#### Fam. IDIOSTROMATIDAE Nicholson.

1886. *Idiostromatidae* Nicholson, Mon. Brit. Strom., Gen. Introd., p. 98.

Stromatoporoids in which the coenosteum is typically cylindrical, being then simple, branched or fasciculate; also massive or spheroidal. Coenosteum composed of porous, tabulated or apparently compact skeletal fibre; skeletal mesh vermiculate, but with definite radial pillars or concentric laminae; tabulate axial tube present in cylindrical forms; tubes otherwise distributed irregularly through coenosteum. Astrorhizae absent.

Genera: *Idiostroma* Winchell.  
*Stachyodes* Bargatzky.  
*Amphiphora* Schulz.

In his first definition of the family Idiostromatidae Nicholson included the genus *Hermatostroma*, which he subsequently (Mon. Brit. Strom., p. 215) removed to the Stromatoporidae.

### **Idiostroma** Winchell.

1867. *Idiostroma* Winchell, Proc. Amer. Ass. Adv. Sci., p. 99.

1886. *Idiostroma* Nicholson, Mon. Brit. Strom., Gen. Introduct., p. 99.

Stromatoporoids in which the coenosteum is typically cylindrical, sometimes fasciculate, sometimes massive or sub-massive. Radial pillars and concentric laminae distinct; skeletal fibre porous. Cylindrical forms may have tabulate axial canal. Astorhizae absent.

Genotype: *I. caespitosum* Winchell, Proc. Amer. Ass. Adv. Sci., pp. 96, 98, 99, 1867. Bassler, Bibliographic Index of American Ordovician and Silurian Fossils, Vol. I., p. 659, 1915. Devonian of North America.

The internal structure of the forms originally described by Winchell (1867) in erecting the genus is unknown, so that the relations between *I. caespitosum* Winchell and *I. gordiaceum* Winchell of the Devonian of North America and the species described by Nicholson (1886) cannot be ascertained. The genus *Idiostroma* as defined by Nicholson appears to include two forms which agree in the shape of the coenosteum, but which have distinct types of skeletal mesh. The species first described, and regarded by Nicholson as a typical form of the genus, *I. roemeri* Nich. of the Rhenish Devonian, has well defined continuous radial pillars which pass through a number of concentric laminae. *I. oculatum* Nich., of the Devonian of Great Britain and Germany, has, on the other hand, an internal structure approximating to that of a *Stromatoporella*. The concentric laminae are well developed, and connected by short, stout radial pillars, which rarely pass through more than one interlamina space. These differences in internal structure seem to suggest that the genus *Idiostroma* includes in reality forms which are generically distinct, but which have, probably from environmental causes, assumed a similar mode of growth, so that a cylindrical coenosteum, usually with an axial canal, is produced. It may be suggested further that *I. roemeri* probably has affinities with those species of *Stromatopora* in which the radial pillars are dominant, or with *Hermatostroma*, while *I. oculatum* may be a form of *Stromatoporella*. Similar cases are not rare among recent corals, so that the possibility of such variation in another important reef-building organism should not be overlooked.

## IDIOSTROMA OCULATUM Nicholson.

(Pl. IX., fig. 6, Text-fig. 4.)

1886. *Idiostroma oculatum* Nicholson, Mon. Brit. Strom., p. 101, figs. 14, 15.1892. *Idiostroma oculatum* Nicholson, Mon. Brit. Strom., p. 225, figs. 32, 33; pl. XXIX., figs. 8-11.

Coenosteum cylindrical or massive, usually of small size; non-latilaminar; built up of straight concentric laminae and stout radial pillars, which usually pass through but one interlaminar space; laminae 4 in 1 mm., pillars less regularly distributed; astrorhizae absent; axial canal sometimes present in cylindrical coenosteum.

The specimens are usually much weathered, but appear to show the external characters described by Nicholson for this species. The largest example is hemispherical and has a radius of 25 mm. The cylindrical examples, which are possibly fragments of fasciculate coenosteum, are more abundant, and have diameters ranging from 10 to 20 mm.; the exposed surfaces are usually rather powdery, so that the finer structural details are not observable. The most conspicuous features of the surface are the circular apertures of the "Caunopora" tubes.

In vertical sections (transverse) the mesh characteristic of *Stromatoporella* is seen. The skeletal fibre is porous and rather coarse, and the horizontal laminae are separated by interlaminar spaces which are equal in diameter to the width of the laminae. The horizontal laminae are usually straight and of even thickness, but may thin out, particularly in regions of irregular growth, and give the appearance of tabulae crossing "zooidal tubes." "Interlaminar septa" like those described by Nicholson as being present in *Stromatoporella eifeliensis* Nich. or *S. solitaria* Nich. are present but not abundant. These irregularly vesicular partitions seem to indicate some interruption in the growth of the horizontal laminae, since these also become thinner as they approach the region where the "septa" are developed.

"Caunopora" tubes are abundant and regularly developed in all specimens available. They reach a diameter of 0.5 mm. or more, and are often filled with secondary calcite, so that the nature of the original walls is not discernible, and the tabulae are often completely obliterated. In some specimens, the "Caunopora" tubes have horizontal tabulae, but of commoner occurrence is the type which has the funnel-shaped tabulae characteristic of *Syringopora*. The "Caunopora" tubes form in the cylindrical coenosteum a very regular network, and are frequently connected by horizontal stolons, which may also give rise to new tubes or corallites. In those specimens in which the mode of growth of the "Caunopora" tubes near the centre of the coenosteum can be



observed, no change in the nature of their walls is seen. Nicholson has noted (Mon. Brit. Strom., p. 102) that in some specimens of *I. oculatum*, presumably from the Middle Devonian of Büchel, Germany, though this is not definitely stated, the "Caunopora" tubes have the normal thickened walls in the outer parts of the coenosteum, but lose these and communicate directly with the interlaminar spaces near the centre. He argued at first that the "Caunopora" tubes were thus clearly part of the organism in which they were found, and that they were probably connected with the reproductive processes. In his later description of *I. oculatum*, however (Mon. Brit. Strom., p. 227), he suggests that the evidence is inconclusive, since the tubes are not always present, and absorption of the walls of a foreign organism by the enclosing stromatoporoid may well take place.

Most specimens have an axial region which in its structure is distinct from the rest of the coenosteum. One example (Coll. National Museum, Melbourne, Reg. No. 13781) has an axial canal which is now filled with coarsely crystalline calcite. The skeletal mesh in its vicinity is rather irregular, and the "Caunopora" tubes, which are of the *Syringopora* type, run parallel to the axial region, as shown by the circular cross-sections in a transverse section of the coenosteum. The other examples, however, have in transverse section a fairly well defined circular or elliptical axial zone of porous skeletal fibre, which forms an irregularly vermiculate mesh. This zone is separated from the outer region of the coenosteum, in which the mesh is normal, by the first of the concentric laminae, which may be somewhat thicker than usual. A similar structure has been figured by Nicholson (Mon. Brit. Strom., pl. XXIX., Fig. 9) in an example from Shaldon, near Teignmouth, South Devon, and the occurrence of similar reticulate tissue is mentioned in the description of the species (*Ibid.*, p. 226).

Tangential sections passing through the horizontal laminae show these to be compact plates with occasional perforations. Those parts of the sections which pass through an interlaminar space show a grouping of the pores of the skeletal mesh around the "Caunopora" tubes, and the radial pillars are sometimes seen as isolated, rounded, solid cross-sections.

In the form of the coenosteum and the type of skeletal mesh these specimens are identical with the species *I. oculatum* Nich. described from European localities and figured on pp. 226-227 of Nicholson's monograph. That Figs. 8 and 9 on Plate XXIX. represent an example of the same species is not at all certain, since the skeletal mesh is of an entirely distinct type, in which the radial pillars are the dominant skeletal elements. As noted



above in dealing with the genus, it is not impossible that it may contain forms which, regarded from the point of view of internal structure, and particularly of the skeletal mesh, should be considered to be generically distinct. *I. oculatum* has in this respect affinities with members of the genus *Stromatoporella*, though its mesh cannot be identified with that of any species at present known.

Horizon.—Yeringian.

Locality.—Mitchell's Quarry, Cave Hill, Lilydale.

Figured specimens.—Coll. National Museum, Melbourne, Reg. Nos. 13766 (Pres. F. Chapman, Esq., 7.6.02) and 13779 (Pres. F. Chapman, Esq., 20.12.15).

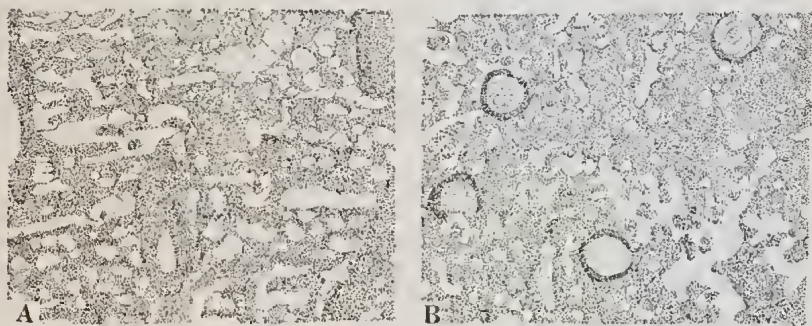


Fig. 4A. *Idiostroma oculatum* Nicholson. Mitchell's Quarry, Cave Hill, Lilydale. Vertical (transverse) section. Coll. National Museum, Melbourne, Reg. No. 13766.  $\times 9$  approx. Yeringian.

Fig. 4B. Same species. Tangential section of the same specimen.  $\times 9$  approx.

### Remarks on the Stromatoporoid Assemblage of the Lilydale Limestone.

At the present stage in the work on Victorian stromatoporoids it is impossible to give a complete analysis, based on the evolutionary stages reached by the various species, of the Lilydale fauna. The affinities of the fauna will therefore be treated in more detail after the description of other Victorian faunas, when conclusions and comparisons based on the evolutionary changes observed in the stromatoporoids can more appropriately be drawn.

The stromatoporoid fauna of the Lilydale limestone is rich in individuals and species, and consists, so far as is known at present, of eighteen forms belonging to six genera. Of these forms six are new, while the rest are identical with, or have close affinities with, species already described from North America and Europe.

The horizons on which these forms most usually occur elsewhere are indicated below:—

Species.	Horizon.	Localities.
<i>Actinostroma verrucosum</i> Goldfuss ..	Givetian .. ..	Devon, Eifel, Paffrath
<i>Clathrodictyon regulare</i> (von Rosen) ..	Wenlock .. ..	Gt. Britain, Gotland
<i>Syringostroma niagarense</i> Parks ..	Niagaran .. ..	Michigan
<i>S. ristigouchense</i> (Spencer) ..	Helderbergian ..	Canada
<i>S. densum</i> Nich. ..	U. Helderbergian ..	Ohio
<i>Stromatopora joveolata</i> Girty ..	L. Helderbergian ..	New York
<i>S. hüpschii</i> (Bargatzky) ..	Givetian .. ..	Devon, Eifel, Paffrath
<i>S. bucheliensis</i> (Barg.) ..	Givetian .. ..	Devon, Eifel, Paffrath
<i>S. bucheliensis</i> var. <i>digitata</i> Nich. ..	Givetian .. ..	Devon, Eifel, Paffrath
<i>Stromatoporella granulata</i> Nich. ..	Hamilton .. ..	Ontario
<i>S. damnamensis</i> Nich. ..	Givetian .. ..	Devon, Eifel
<i>Idiostroma oculatum</i> Nich. ..	Givetian .. ..	Devon, Paffrath

Of these species seven are Middle Devonian, being well-known British, German (Givetian), or North American (Hamilton) forms, three come from the Helderbergian of North America (Lower-Lower Middle Devonian), and two occur in the Wenlock and Niagaran (Middle Silurian). *Clathrodictyon regulare* (von Rosen), one of these species, while being highly characteristic of the Wenlock, has also been recorded from the Devonian (Coblentzian-Eifelian) of the Ancenis Basin, France (Le Maitre, 1934), an occurrence which is interesting in view of the presence of this species in the Middle Devonian limestones of Buchan, Victoria. Another form occurring in the Chalonnès limestone of the Ancenis Basin, described as *Cl. striatellum* (Le Maitre, 1934), is very similar to *Cl. calamosum* Ripper of the Lilydale limestone.

It is obvious, therefore, that this fauna has little in common with the Wenlock stromatoporoid fauna of Great Britain or Gotland, and its affinities with the Devonian fauna are emphasized by the presence of species of *Actinostroma* belonging to the group of *A. clathratum* Nich., of species of *Clathrodictyon* belonging to the group of *Cl. striatellum* (d'Orb.), in which the skeletal structure is of an advanced type, and that of *Cl. chapmani* Ripper; of various transients between *Syringostroma* and *Stromatopora*, and of those types of *Stromatopora* most common in the Middle Devonian, in which the radial pillars dominate the skeletal mesh.

### Summary and Conclusions.

The description of the stromatoporoid fauna of the limestone at Mitchell's Quarry, Cave Hill, Lilydale, is concluded in this paper, which deals with the species of *Syringostroma*, *Stromatopora*, *Stromatoporella*, and *Idiostroma*. Reviewing the whole fauna as far as it is at present known, it may be noted that a high proportion of the species can be identified with forms occurring elsewhere in the Middle Devonian; three occur in the Helderbergian (Lower and lower part of the Middle Devonian)

of North America, while only two are typical of the Wenlock limestone of Great Britain and the Niagara of North America. As will be shown later from evolutionary considerations, the new forms described by the writer are usually of advanced types, and it is obvious that the Lilydale stromatoporoid fauna has very little in common with that of the British Wenlock, to which the Lilydale limestone has generally been considered to be equivalent, and should rather be correlated with European and North American Devonian faunas.

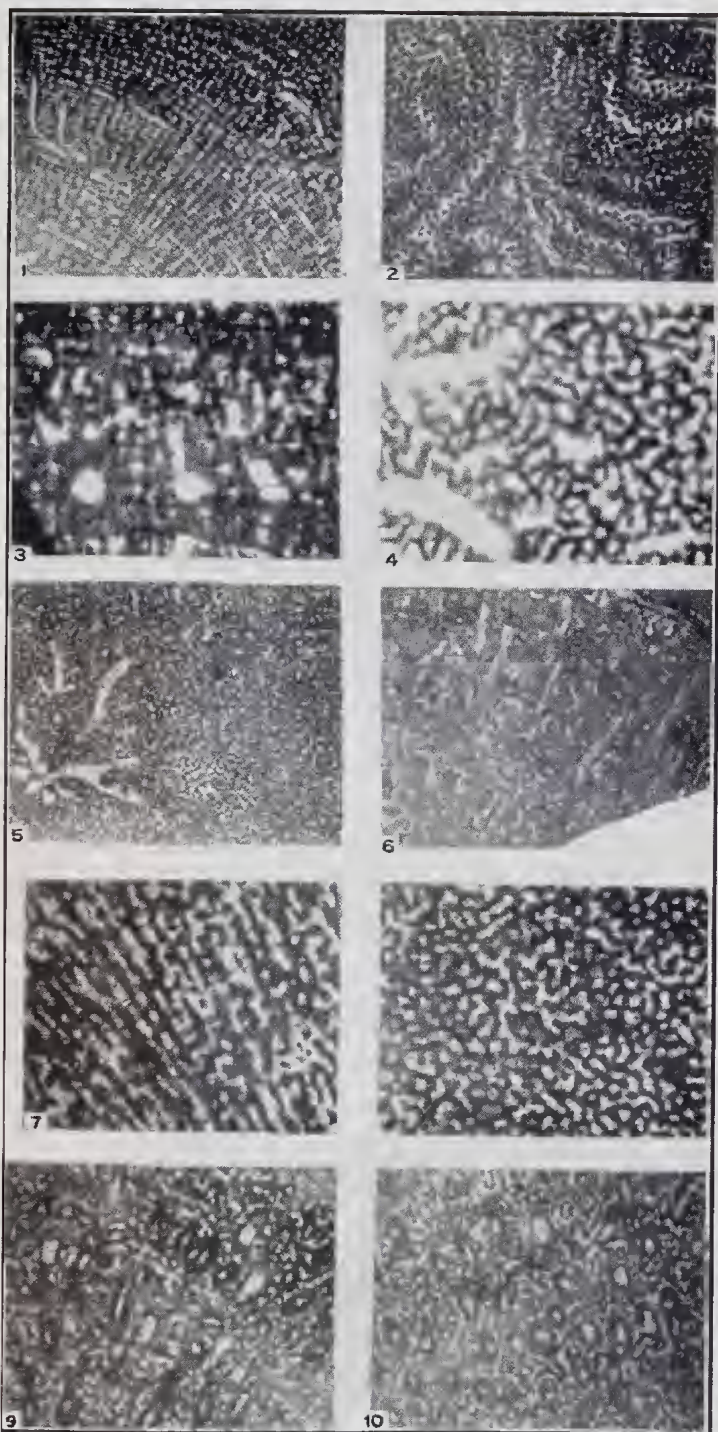
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**Explanation of Plate VIII.**

- Fig. 1. *Syringostroma* aff. *ristigouchense* (Spencer). Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. Dept. of Geology, Univ. of Melbourne, Reg. No. 1619.  $\times 4$  approx.
- Fig. 2. Same form. Tangential section of the same specimen.  $\times 4$  approx.
- Fig. 3. *Syringostroma densum* Nicholson. Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. Dept. of Geology, Univ. of Melbourne, Reg. No. 1620.  $\times 8.5$  approx.
- Fig. 4. Same species. Tangential section of the same specimen.  $\times 8.5$  approx.
- Fig. 5. Same species. Tangential section of the same specimen, showing an astrorhizal system.  $\times 4$  approx.
- Fig. 6. *Stromatopora bücheliensis* (Bargatzky) var. *digitata* Nicholson. Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. National Museum, Melbourne, Reg. No. 13794.  $\times 4$  approx.
- Fig. 7. *Stromatopora* aff. *hüpschii* (Bargatzky). Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. National Museum, Melbourne, Reg. No. 13790.  $\times 4$  approx.
- Fig. 8. Same form. Tangential section of the same specimen.  $\times 4$  approx.
- Fig. 9. *Stromatopora bücheliensis* (Bargatzky). Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. National Museum, Melbourne, Reg. No. 13763.  $\times 4$  approx.
- Fig. 10. Same species. Tangential section of the same specimen.  $\times 4$  approx.



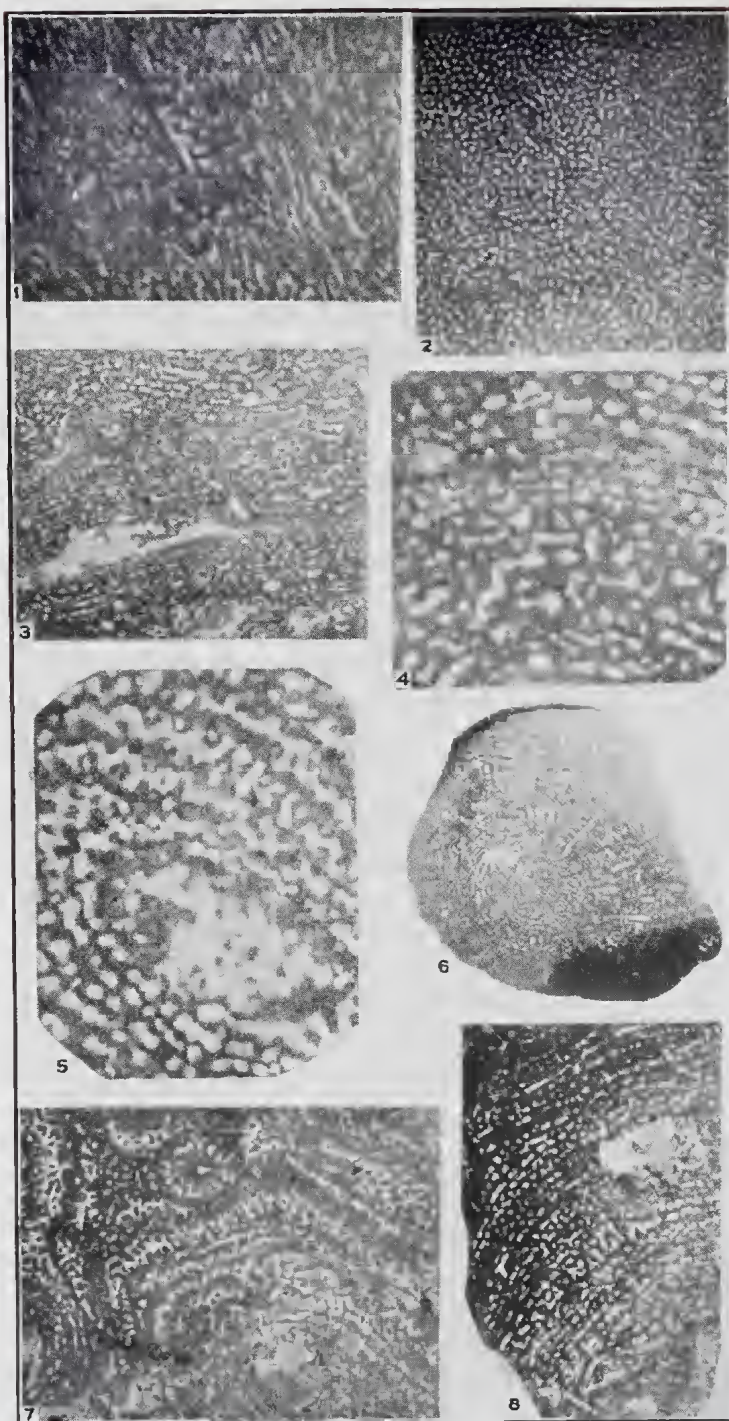


Lilydale Stromatoporoids.









Lilydale Stromatoporoids.

**Explanation of Plate IX.**

- Fig. 1. *Stromatopora lilydalensis*, sp. nov. Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. National Museum, Melbourne, Reg. No. 13768.  $\times 4$  approx.
- Fig. 2. Same species. Tangential section of another specimen. Coll. National Museum, Melbourne, Reg. No. 13785.  $\times 4$  approx.
- Fig. 3. *Stromatoporella granulata* Nicholson. Mitchell's Quarry, Cave Hill, Lilydale. Vertical section. Coll. Dept. of Geology, Univ. of Melbourne, Reg. No. 1622.  $\times 4$  approx.
- Fig. 4. Same species. Vertical section of the same specimen.  $\times 8.5$  approx.
- Fig. 5. Same species. Tangential section of the same specimen.  $\times 8.5$  approx.
- Fig. 6. *Idiostroma oculatum* Nicholson. Mitchell's Quarry, Cave Hill, Lilydale. Transverse section. Coll. National Museum, Melbourne, Reg. No. 13779.  $\times 2$ .
- Fig. 7. *Stromatoporella* cf. *damuionensis* Nicholson. Mitchell's Quarry, Cave Hill, Lilydale. Tangential section. Coll. National Museum, Melbourne, Reg. No. 13788.  $\times 4$  approx.
- Fig. 8. Same form. Vertical section of the same specimen.  $\times 4$  approx.

[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. II., 1937.]

ART. XIV.—*Studies on Australian Aquatic Phycomycetes.*

By KATHLEEN M. CROOKS.

[Read 12th November, 1936; issued separately 19th July, 1937.]

**Introduction.**

In recent years, investigations have been carried out in different countries, notably Great Britain, America, Germany, and Denmark, to ascertain the nature of the aquatic fungus flora. The rarer members, Blastocladia, Sapromyces, and Rhipidium were not recorded until late in the nineteenth century, when they were described by Cornu (1871), Reinsch (1878), and Thaxter (1894-1896), although investigations in the Saprolegniaceae had commenced much earlier. Early in the twentieth century accounts of aquatic fungi by Von Minden (1912) in Germany, and Petersen (1910) in Denmark were published, but only occasional records appeared from then until 1922, since when, this group, particularly the rarer families, Blastocladiaceae and Leptomitaceae, has drawn the attention of a number of workers. Recently, Lund (1934) has contributed to the records of the aquatic fungi in Denmark, and Apinis (1929) has investigated the Saprolegniaceae in Latvia. Coker (1922-1926) and his workers thoroughly studied the group in America, followed by other papers—Kanouse (1925, 1927, 1932), Couch (1926, 1927, 1932), Harvey (1930), and Sparrow (1932, 1936). In Great Britain, the earliest records of aquatic fungi were by Massee (1891) and Ramsbottom (1914-1916), but since 1932 other mycologists have contributed to this group, namely Barnes and Melville (1932), Cook and Forbes (1932), Forbes (1935), and just before the completion of this paper Sparrow (1936) published the results of an extensive investigation. Hitherto, in Australia, the attention of workers has been confined to the terrestrial fungus flora, with the exception of records by Rodway (1897), Hardy (1910), and Johnston (1917, 1921) of *Saprolegnia ferax* associated with a disease in fish.

The present writer gives an account of some members of the Blastocladales and Saprolegniales and compares them with those recorded in other countries. None of the fungi described in this paper, with the exception of *Saprolegnia ferax*, has previously been described from Australia.

The writer was particularly interested in the rarer Blastocladales and Leptomitaceae, and, when collecting, efforts were made to secure these forms rather than the filamentous fungi—



Saprolegniaceae or Pythiaceae, although the latter were also obtained. The fungi have been collected chiefly from artificial ponds, and, only in three instances, have they been collected from natural waters—Yarra River at Rudder Grange, Barham River at Apollo Bay, and McCallum's Creek near Maryborough.

### Methods of Collection.

The methods used were those employed by other workers on this group—i.e., the Blastocladales and Leptomitaceae—the setting of traps containing suitable baits in a likely locality. The baits used were twigs, rose hips, apples, oranges, bananas, grapes, prunes, *Cotoneaster* berries, *Crataegus* berries, *Solanum pseudocapsicum* berries, and *Japonica* fruits. They were put into fine wire-mesh baskets, which were placed in the pond or stream, anchored to the shore by a long wire, and submerged for one or two months. When the baits were brought into the laboratory, they were thoroughly washed in running water for about a day, and then transferred to sterile distilled water, in glass dishes with loosely fitting covers, so as not to exclude the air. Examination of the baits was commenced immediately. In most cases, the pustules formed by *Blastocladia*, *Gonapodya*, *Sapromyces*, and *Rhipidium* were visible when brought in and sometimes the fruits were covered thickly with these whitish patches. Infection of the fruits and further development of the plants, e.g., the formation of resting spores, continued after they were placed in sterile water.

The filamentous fungi, e.g., Saprolegniaceae, which usually occurred on twigs, but also on some fruits, rose hips, and *Crataegus* berries, did not appear for a few days after the baits were brought in. They were then transferred to dishes of sterile water containing boiled halved hemp seeds, on which they grow readily. The descriptions of the forms included in this paper are from the growth on hemp seeds.

In a couple of instances, pond water was brought in to the laboratory, and immediately baited with boiled hemp seeds. After a few days, the filamentous forms, e.g., *Dictyuchus* and *Achlya*, appeared. Pond water was also baited with grapes and prunes, when *Pythiomorpha* was obtained. This genus also appeared on rose hips after they had been in the laboratory for some days. For *Blastocladia*, *Sapromyces*, *Rhipidium*, and *Gonapodya*, the satisfactory baits are apples, rose hips, *Crataegus* berries, and *Japonica* fruits. Oranges were used as baits on two occasions but only *Pythiomorpha* was obtained.

Owing to the difficulty of keeping permanent cultures of the Blastocladales and Leptomitales, plants of these members were mounted on slides in glycerine jelly for reference purposes.

## Cultural Methods.

### (i) SAPROLEGNIALES.

When the filamentous threads appeared on the bait, they were lifted off, and transferred to dishes of sterile water containing boiled halved hemp seeds. Sometimes mixed cultures were obtained, but as *Saprolegnia*, *Achlya*, or *Dictyuchus* readily formed sporangia, one of the latter was cut off, transferred to another dish, and thus pure cultures were obtained. Sometimes the sex organs developed readily, e.g., in *Saprolegnia ferax*, but in other cases, difficulty was experienced in obtaining them, as in *Achlya conspicua*. Their development was often very localized—appearing in only one place in a dish containing several hemp seeds.

A species of *Achlya*, also one of *Dictyuchus* (later regarded as *D. sterile*, or one grain of a heterothallic *Dictyuchus*), did not develop sex organs on hemp seed, and attempts were made to obtain them by growing the fungi on hemp seeds in different culture media, also on solid media.

The following media were used:—

- (a) Agar for Saprolegniaceae (recommended by W. Höhnk 1932)—1 litre distilled water, 8–10 gm. agar, 5 gm. carragen (or if not available 5 gm. agar), 0.5 gm. gm. dextrose, 0.05 gm. citric acid.  
 Stock solution—0.005 gm.  $\text{KH}_2\text{PO}_4$ , 0.000025 gm.  $\text{NH}_4\text{NO}_3$ , 0.000025 gm.  $\text{Mg}.\text{SO}_4$ , 0.000025 gm.  $(\text{NH}_4)_2\text{SO}_4$ .
- (b) Levulose and peptone agar—Levulose 1.2 per cent., peptone 0.1 per cent.
- (c) Glucose and peptone agar—Glucose 1.2 per cent., peptone, 0.1 per cent., agar 1.5 per cent.
- (d) Solutions of maltose and peptone in water—1. Maltose and peptone .0125 per cent. each. 2. 0.3 per cent. maltose and 0.1 per cent peptone. 3. 0.05 per cent. maltose and 0.025 per cent. peptone.
- (e) Solution of Witte's peptone—0.1 per cent., leucin 0.1 per cent., maltose 0.5 per cent.
- (f) Solution of saccharose—0.025 per cent. in which cubes of egg albumen were placed instead of the hemp seeds.

In all of these good growth was obtained, but no sexual organs. Kanouse (1932) had considerable success with some of these peptone cultures in combination with maltose or glucose, and also with the addition of leucin, in inducing the formation of oogonia and antheridia in *Saprolegnia parasitica*—a form which until then was regarded as sterile; but with these media, the writer could not obtain sex organs in either the *Achlya sp.* or *Dictyuchus*

*sp.* A method described by Couch (1932) which was very successful with *Leptolegnia candala* was also tried, together with certain modifications of it, by transferring the growth from the maltose and peptone solutions described above, to sterile water. In only one case were oogonia obtained; the *Achlya* growth was transferred from a solution containing 0.025 per cent. maltose and 0.025 per cent. peptone to sterile water, and after three to four days, numerous oogonia appeared, but no antheridia. The oogonia degenerated without the development of eggs.

Experiments were then tried using heteroauxin, a plant growth hormone, and an A-Z solution, a solution containing traces of the rarer elements; in this case 35 were present. The following concentrations were used:—

- (a)  $\frac{1}{100,000}$  heteroauxin in maltose and peptone, 0.025 per cent each.
- (b)  $\frac{1}{50,000}$  heteroauxin in 0.025 per cent. maltose and 0.025 per cent. peptone.
- (c)  $\frac{1}{50,000}$  heteroauxin in 0.025 per cent. saccharose.
- (d)  $\frac{1}{100,000}$  heteroauxin in water.
- (e) A-Z solution, 2-6 drops in 0.025 per cent. maltose and 0.025 per cent. peptone.
- (f) A-Z solution, 2-6 drops in 0.025 per cent. saccharose solution.

In all cases, a good vegetative growth was obtained but no sexual organs. When the mycelium was transferred from these solutions to sterile water, oogonia appeared in all cases after a few days, but were most numerous in the solutions of  $\frac{1}{50,000}$  heteroauxin. Two antheridia appeared, and, in all cases the oogonia again degenerated after a day or two, suggesting either that the sexuality-inducing substance was not present in sufficient amounts to carry the development farther, or, that the plant in question is the female strain of a heterothallic species.

A series of experiments was also carried out, following those of Leonian (1936), an account of which appeared just before the completion of this paper. Using pea-infusion as the sexuality-promoting substance, Leonian obtained considerable success with *Phytophthora cactorum*. However, in the case of *Achlya sp.*, the pea-infusion did not induce the formation of any sexual organs, not even the oogonia obtained in the previous solutions.

It is evident that physiologically each species is extremely specialized, as has been shown in the past by the experiments of different workers, and substances which may induce the formation of oogonia in one species will have no effect in even another species of the genus.

(ii) BLASTOCLADIALES AND LEPTOMITACEAE.

Previous workers have shown the extreme difficulty of obtaining these forms in culture. Coker (1923) has obtained a slow growth of *Sapromyces* in vegetable juices obtained by boiling corn grains or peas, and Von Minden (1916) described a method of growing *Araiospora* and *Rhipidium europaeum* in culture, but all attempts with the Blastocladales have given negative results. Since these forms grow readily on rose hips, a solid medium was tried in which an extract from rose hips was solidified with agar. An infusion from rose hips was also used, but no growth was obtained.

Slopes of carrot partly covered with water were inoculated with plants of *Blastocladia*, *Sapromyces*, and *Gonapodya*, but gave negative results. A bacterial scum quickly develops, but this is not the only factor prohibiting growth. *Sapromyces* was found to grow slowly in prune juice, but no new plants appeared, showing that neither the zoospores nor resting spores germinated. It is suggested that owing to the extreme sensitivity of the protoplasm in these forms, the mere act of disturbing them by transference from the original substratum, renders them incapable of germination.

Another method was tried, so as to have cultures of these forms for continuous study. It was found that when baits were brought in to the laboratory, pustules were formed in addition to those already present. Fresh apples were added to dishes containing infected apples, in the hope that they would be attacked, but the result was negative. Even when pustules were transferred directly to the fruits no further infection occurred, although the fungi apparently continued to grow. It would appear that, in the lakes or streams in which the traps are placed, bacterial action is responsible for the softening of the fruit surface before fungal attack. Naturally baits brought into the laboratory were washed frequently to keep down bacterial contamination, and it was thought that this may have prevented the apples from being attacked. Sterile tap water was used for washing the baits at first, but later on just ordinary tap water. Another experiment was tried in which fresh apples were placed in dishes with the bait, and the water was not changed. After two months, the apple skin was softened, but no infection had occurred. It is therefore concluded that in lakes, etc., decomposing bacteria and organisms, not found in tap water, prepare the fruit surface for fungal attack.



The fact that these fungi often possess rhizoidal systems should not be wholly responsible for the difficulty in obtaining them in culture, but evidently, parts of plants, e.g., filaments broken off, do not produce new plants as in Saprolegniaceae, Pythiaceae, etc., and the formation of plants must be entirely dependent on the germination of the spores—the protoplasm of which is extremely sensitive to any disturbing forces and to environment.

### Description of the Fungi in Culture.

#### SAPROLEGNIALES. Saprolegniaceae.

##### SAPROLEGNIA FERAX (Gruith.) Thuret.

Ann. Sci. Nat. Bot., Series 3, 14: 214, pl. 22, 1850.

Saprophytic on *Crataegus* fruits at University, collected 5th April, 1935; growth rather coarse on hemp seed; sporangia, terminal, cylindrical, proliferating with an average diameter of  $54.5\mu$ , and a great variation in length, often constricted by the mouths of earlier sporangia; gemmae pyriform to oval, and occasionally bearing oogonia, frequently in chains (Fig. 1, B); oogonia spherical to oval, occasionally cylindrical when developed in an empty sporangium, borne in a terminal, lateral, or intercalary position on the hyphae; wall about  $1.9\mu$  thick, with conspicuous pits which have a diameter range of  $6-10\mu$ , average diameter  $7\mu$ ; frequently, a narrow hypha is observed to pass into the cavity of the oogonium from the apex of the oogonial stalk; spores—1-30 per oogonium; centric,  $18-34\mu$  in diameter, usually  $25\mu$ ; antheridia found on about 60 per cent. of the oogonia; mainly androgynous but of declinuous origin when the oogonia are borne terminally. When the oogonium arises on a short lateral branch, the antheridium arises from the stalk of the oogonium; antheridia usually slender and branched, but only one or few found on any one oogonium (Fig. 1, D-G).

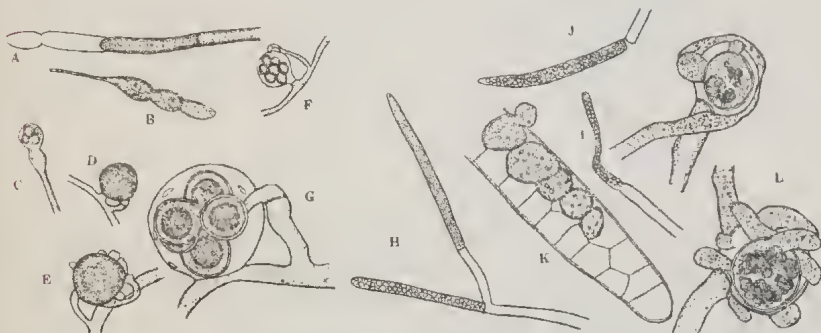


FIG. 1.—A-G, *Saprolegnia ferax* (Gruith) Thuret. H-L, *Dictyuchus monosporus* Leitgeb. A, Sporangia, B, Gemmae, C, Gemma containing eggs, D, E, F, Oogonia and Antheridia. All  $\times 33$ . G, Oogonium containing mature oospores.  $\times 207$ . H, I, Sporangia of normal type.  $\times 33$ . J, Resting sporangium about to fall off.  $\times 33$ . K, Portion of sporangium showing network.  $\times 207$ . L, Oogonia with encircling antheridia.  $\times 207$ .



There has been much discussion as to whether *S. ferax* and *S. mixta* should be regarded as two distinct species. Formerly *S. ferax* was distinguished from *S. mixta*, in possessing antheridia on usually less than 10 per cent. of the oogonia, but it has been found that the same culture may at different times vary in the percentage of oogonia-bearing antheridia. According to Forbes (15), the species formerly known as *S. mixta* is only a growth form of *S. ferax*, and the same applies to *S. monoica*, so that *S. ferax* is regarded as one good species which shows different growth forms under varying environmental conditions. Hence, the form in question, since it possesses antheridia on approximately 60 per cent. of the oogonia, most closely approximates to *S. ferax* "*forma mixta*."

#### ACHLYA CONSPICUA.

Coker in "The Saprolegniaceae," 1923, p. 131.

Saprophytic on *Crataegus* fruits and twigs in lake at University, 5th April, 1935: this fungus has a coarse white growth on hemp seed, the hyphae reaching a diameter of  $80\mu$ ; sporangia abundant, arising by lateral branching,  $90-400\mu$  in length and  $18-50\mu$  in breadth (Fig. 2 C); gemmae frequently formed especially in old cultures; they resemble sporangia in shape but are larger, frequently have prongs, giving a forked appearance; oogonia not always developed, but when present are borne laterally on the main hyphae; spherical in shape,  $55-80\mu$  diameter; the walls are not very thick but pitted, the diameter of the pits varying from  $5.5-7.5\mu$ . Usually 4-10 oospores are developed in a single oogonium but over 20 have been observed in a few cases, ranging in diameter from  $21-30\mu$ ; eggs rarely mature, but nearly always degenerate immediately and become filled with oil drops. When they do mature, the eggs are sub-centric, smaller droplets surrounding the subcentric larger globule; Antheridia always present, usually androgynous, but occasionally declinous, arising near the oogonial stalk from the main hypha, or frequently from the oogonial stalks themselves; antheridia are simple or branched, one or sometimes two to each oogonium, usually touching the oogonium by foot-like projections (Fig. 2, D, E).

#### ACHLYA AMERICANA var.—MEGASPERMA var. nov.

Saprophytic on rose hips, in lake in Fitzroy Gardens, Melbourne, 20th July, 1935; hyphae variable in diameter, but mainly coarse reaching a diameter of  $100\mu$ ; sporangia tapering towards the tip, usually up to  $350\mu$  in length, and about  $40\mu$  in the widest part; gemmae few, in chains of 2 or 3 (Fig. 3, E); oogonia are numerous, borne in a racemose fashion along the hyphae; oogonial stalks usually about the same length as the diameter of the oogonium or less than  $\frac{1}{2}$ , rarely  $1\frac{1}{2}$  times the diameter of the oogonia; the latter are occasionally borne terminally on the

hyphae; oogonia spherical, mainly  $40-100\mu$  in diameter, walls thin and pitted, the pits usually fairly conspicuous; oospores  $24-31\mu$  in diameter, average  $27\mu$ , 2-20 per oogonium, usually 6-8, eccentric; antheridia branched, androgynous, but occasionally diclinous, one to four on each oogonium, one antheridium often supplying two oogonia: antheridia usually arise from the main hyphae, occasionally from the oogonial stalk, and are slender, long and branching (Fig. 3, F. G): In the cultures of this fungus, it was found that the eggs frequently disorganized before reaching maturity, leaving the oogonium filled with oily masses.

This species appears to resemble *A. americana* but differs from the description of the type species in the larger size of the oospores, which rang from  $24-31\mu$ , average diameter  $27\mu$ , as against  $18.5-25\mu$ , average  $22\mu$  of the latter. Several workers found it impossible to separate *Achlya de Baryana* and *Achlya americana* as two distinct species; but Forbes (1935) distinguishes them as follows:—In *A. de Baryana*, the oogonial walls are unpitted and some diclinous antheridia occur, while in *A. americana*, the oogonial walls are pitted, and the antheridia are consistently androgynous. Coker describes a form referred to *A. americana*, in which the oogonial walls are pitted, but the antheridia may occasionally be diclinous, so that our species, having pitted oogonial walls, occasional diclinous antheridia, the latter sometimes arising from the oogonial stalk, a feature never found in *A. de Baryana*, seems to be a variety of *A. americana*.

Owing to the large size of the oospores, this form is referred to *A. americana* var. *megasperma* var. nov.

Another variety of *A. americana*, namely, *A. americana* var. *cambrica*, possesses characters not found in this species, namely oogonia with thick yellowish walls, and oospores with a very thick two-layered wall, and  $23-26\mu$  in diameter.

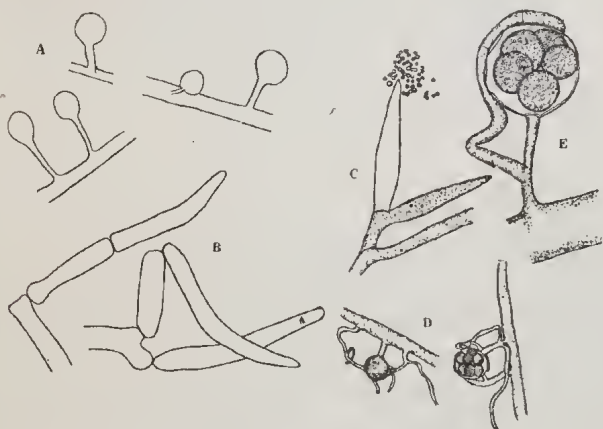


FIG 2.—A, B, *Achlya* sp. ? C-E, *Achlya conspicua* Coker. A, Oogonia.  $\times 33$ . D, Oogonia with androgynous antheridia.  $\times 33$ . E, Oogonium with antheridium.  $\times 125$ .

## ACHLYA OBLONGATA.

de Bary. Bot. Zeit.: 646, pl. 10, figs. 7-9, 1888.

Saprophytic on silver-fish; collected 17th June, 1936; mycelial growth fairly coarse, hyphae up to  $90\mu$  diameter; sporangia typical of the genus, but occasionally dictiosporangia occur; zoospores  $9-12\mu$  diameter; gemmae frequently formed and are oval or elongated; oogonia very large, oval, pyriform or occasionally spherical,  $85-300\mu \times 70-160\mu$ , borne on lateral branches, terminally on the main hyphae or rarely intercalary; wall of oogonia thin and unpitted; eggs  $12-30$  per oogonium, fairly small,  $23-30\mu$  in diameter, mostly about  $26\mu$ , sub-centric, with a sheath of oil droplets all or most of the way around the protoplasm (Fig. 3, C, D); eggs at first dark, becoming lighter in appearance, but rarely maturing; antheridia long, slender, declinuous, usually several wound around each oogonium, tuberosus at the point of contact with the oogonium (Fig. 3, A, B).

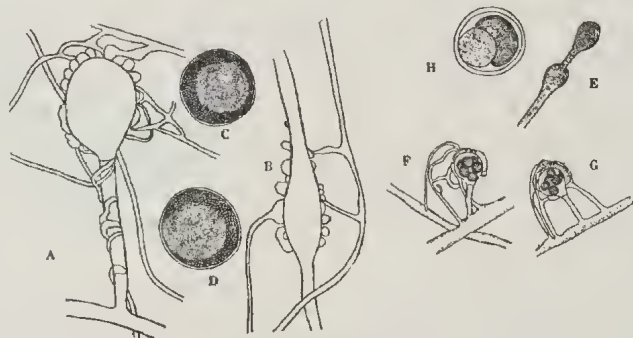


FIG. 3.—A-D, *Achlya oblongata* de Bary. E-H, *Achlya americana* var. *megasperma* nov. var. A, Oogonium with long, declinuous antheridia.  $\times 33$ . B, Intercalary oogonium with antheridia.  $\times 33$ . C, Mature oospore with oil globules all around protoplasm globule.  $\times 207$ . D, Mature oospore with oil globules only partly surrounding protoplasm globule.  $\times 207$ . E, Gemmae.  $\times 33$ . F, G, Oogonia with antheridia.  $\times 33$ . H, Oospore of eccentric type.  $\times 207$ .

## ACHLYA SP. ?

Saprophytic on *Japonica* fruits, lake at Maryborough, collected 13th February, 1936; growth on hemp seed fairly coarse, hyphae,  $15-100\mu$  in diameter; sporangia developed fairly abundantly, producing very small zoospores; gemmae numerous, cylindrical, often very long, terminal ones often tapering to a point, frequently developed in chains along the length of a hypha (Fig. 2, B); oogonia smooth, spherical,  $40-75\mu$  in diameter, with a thin, unpitted wall, borne laterally on the hyphae; at first denser in appearance, but rapidly degenerate and lose their contents (Fig. 2, A); eggs never observed; occasionally slender branches were noticed close to oogonia, but as they were never observed to

approach the oogonia, they cannot be regarded as antheridia, and in most cases, there was no sign of antheridial branches near the oogonia.

It is considered that this may be a female strain of a heterothallic species of *Achlya*. Oogonia have been observed in large numbers, when the fungus was grown in various media (an account of these experiments is given earlier in this paper), but they always disorganized without any sign of oospore formation. Heterothallism in the Saprolegniaceae has been reported previously—in *Dictyuchus* by Couch (1926) and for *Achlya* by Coker (1923). Coker states that his heterothallic species—*Achlya bisexualis* n.sp.—is probably the same as one previously described by him in the Saprolegniaceae, as *Achlya* sp., form without oogonia. Our plant differs from *A. bisexualis* in the shape of the gemmae which are always cylindrical, in contrast to the spherical or pear-shaped gemmae of the latter.

#### DICTYUCHUS sp.

Saprophytic on rose hips, pond in Botanical Gardens, Melbourne; on *Prunus* twigs in lake in Gardens, at Maryborough, Victoria; the main hyphae are 20–60 $\mu$  in diameter, tapering towards the end, where they have a diameter range of 18–35 $\mu$ ; sporangia formed at the tips of the hyphae, and lateral ones are formed by cymose branching; in older cultures, the hyphae themselves become segmented into sporangia, often irregular and bent; frequently the sporangia break away from the hyphae bearing them, and are known as resting sporangia. Sporangia developed along the length of a hypha, if the latter is a fine one, may be thread-like, with only a single row of spores; zoospores 11–14 $\mu$  in diameter, and the spores encyst within the sporangium for a period after which they emerge by individual openings in the sporangium wall, leaving a network of walls in the latter; sexual reproduction not observed.

This isolation agrees in all particulars with *Dictyuchus sterile*. However, Couch has shown that heterothallism is common in the genus *Dictyuchus*, so it is likely also that this may be one strain of a heterothallic form.

#### DICTYUCHUS MONOSPORUS Leitgeb.

Jahrb. f. Wiss. Bot., 7: 357, pl. 22, figs. 1–12, pl. 23, figs. 1–8, 1869.

Saprophytic on rose hips in lake in Fitzroy Gardens, 20th July, 1935; hyphae fairly coarse, reaching diameter of 60 $\mu$ ; sporangia formed abundantly, in sympodia and also along the length of the hyphae; the method of ejection of the spores is typical of the genus; zoospores 9–15 $\mu$  in diameter; oogonia terminal on the branches, spherical, 25–35 $\mu$  in diameter, average 31.5 $\mu$ , with unpitted walls; oospores borne singly in the oogonia, centric,



smooth,  $22-31\mu$  diameter, average  $25.7\mu$ ; antheridia always developed, usually several in contact with each oogonium, diclinous and encircling the oogonia (Fig. 1, L).

This form agrees in general characters with the type species, except that in our species, the oogonia and oospores are slightly larger. Lund (1934) has described a species agreeing with the one in question except that Lund's form has eccentric eggs. Lindstedt (1872) stated that in *D. monosporus*, the oogonia are  $25\mu$  thick, and the sporangia borne only in sympodia, while in *D. Magnusii*, the oogonia are  $30-35\mu$  thick, and the sporangia borne only in rows. In this species other sporangia showed both methods of formation, and while the oogonial size is large, similar to that of *D. Magnusii*, it is thought that this form approximates more closely to *D. monosporus*, particularly in the character of the antheridia, which are always found to wrap around the oogonia. Lund (1934) states that *D. monosporus* developed no sexual organs when grown on hemp seed, but the author has obtained them in hemp seed cultures, although they were not observed in the original substrata, namely, rose hips and twigs.

#### LEPTOMITACEAE.

##### SAPROMYCES REINSCHII (Schroeter) Fritsch.

Österr. Bot. Zeitschr, 43, p. 420, 1893.

Saprophytic on rose hips and apples in lake at University; collected 5th April, 1935; saprophytic on apples in Barham River, near Apollo Bay, collected 1st June, 1936. This form was found in abundance, and was frequently associated with *Gonapodya* and *Blastocladia*. While *Blastocladia* produces a short compact tuft, on the fruits, tufts containing *Sapromyces* alone were not so dense, and projected further from the fruits.

Plant attached to substratum by well-developed rhizoids, the rhizoidal system being often very extensive; basal cell including the rhizoids, varies from  $300-1200\mu$  in length and  $15-30\mu$  in breadth, and produces distally finer branches which are cylindrical, segmented and  $8-15\mu$  in diameter (Fig. 4, A); reproductive organs arise from these branches or from the finer filaments which arise from them; constrictions between the segments usually closed with cellulose plugs; asexual reproduction by zoosporangia borne singly or usually in groups of 2-5 at the end of the filaments or at the constrictions. Zoosporangia  $40-170\mu \times 15-30\mu$  elongate and usually wider about the middle than at either end; zoospores escape by a terminal pore or occasionally germinate inside the sporangium. The method of escape mentioned by Kanouse (1927), in which the whole zoospore mass emerged, surrounded by a membrane which is immediately ruptured, was also observed; sexual reproduction not always



present in the material examined, but if present at all was abundant; oogonia borne terminally or laterally, and often associated with sporangia in the same whorl; oogonia  $41-63\mu \times 29-40\mu$  pyriform to sub-spherical, with a well-developed pedicel. When mature the oogonial walls are covered with a yellowish-brown incrustation which is usually thicker at the apex, and a single spherical oospore is developed within each oogonium; oospores vary in size from  $26-34\mu$ , wall fairly thick, brown externally but colourless when viewed in optical section, occasionally slightly irregular, but the series of irregular ridges noted by Sparrow (1936), were not visible; antheridia always present and usually of diclinous origin; swollen and clavate in shape,  $30-40\mu \times 9-13\mu$ , borne on long, winding, twisted branches,  $4-6\mu$  in diameter, and send a prominent fertilization tube into the oogonium (Fig. 4, B). One example was found of an androgynous antheridium said to be characteristic of *S. androgynous*. On the same plant there were numerous oogonia fertilized by antheridia from different plants, and therefore of diclinous origin (Fig. 4, C). This is interesting, in view of the fact that Sparrow (1932) mentions that experiments were being carried out by P. H. Jordan which seemed to indicate that this

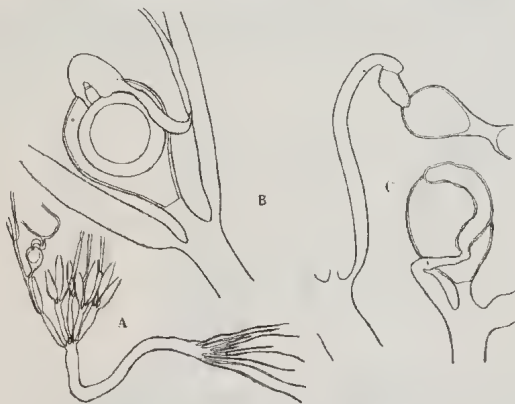


FIG. 4.—*Sapromyces Reinschii* (Schröeter) Fritsch.  
A, Plant showing well developed rhizoidal system and bearing reproductive organs.  $\times 33$ . B, Oogonium with diclinous antheridium.  $\times 207$ . C, Two oogonia from the same plant, one with diclinous antheridium, the other with androgynous antheridium.  $\times 207$ .

species is heterothallic. It has also been noted that a well-developed rhizoidal system is present, as previous workers have suggested that they are not developed. Sparrow (1932) stated that the narrow basal cell is "presumably anchored by hold-fasts," but in all the plants examined in this collection except those that were obviously broken above the point of attachment of the substratum, rhizoids were present (see Plate X., 7, 8).

## RHIPIDIUM AMERICANUM Thaxter.

Bot. Gaz., 21: 320, pl. 22, figs. 1-15, 1896.

Saprophytic on rose hips, in Lake at University, 5th April, 1935; on apples, *Japonica* fruits, *Cotoneaster* berries, in lake in Maryborough Gardens; plant attached to substratum by means of rhizoids, sometimes copious, at other times scanty; basal cell peltate,  $180\text{--}300\mu$  from rhizoids to apex, and in surface view, the apex has an irregularly stellate appearance (Plate X. 6); stalk varies in diameter from  $23\text{--}50\mu$ , and at the top may divide dichotomously to form branches or lobes which spread in a radiate fashion, or may expand into a flattened head which is lobed or branched around its circumference (Fig. 5, A, B); diameter of the apex varies from  $90\text{--}250\mu$ , and has a fairly thick wall  $3\text{--}7\mu$ , but the diameter of the individual lobes range from  $10\mu\text{--}90\mu$ . From this basal cell arise filamentous branches  $150\text{--}700\mu \times 3\text{--}10\mu$ , and they are swollen just above their attachment to the thallus. These filaments are usually segmented, resembling the filaments of *Sapromyces Reinschii*. Zoosporangia borne terminally on the filaments, usually 2 or 3 together, less often singly, ovoid,  $46\text{--}100\mu \times 16\text{--}40\mu$  (Fig. 5, C, D); zoospores observed to emerge in a cylindrical mass surrounded by a thin membrane which ruptures and allows the zoospores to escape; sexual reproduction not observed, although a large number of plants were examined.



FIG. 5.—*Rhipidium americanum* Thaxter. A, B, Peltate thalli showing irregular branching.  $\times 33$ . C, Sporangia occurring singly, or in twos or threes.  $\times 33$ . D, Sporangia.  $\times 125$ . E, Portion of thallus showing thick walls, and the basal parts of filaments.  $\times 207$ .

The nature of the thallus, although constant in form, in the plants examined here, is very varied as shown by the descriptions of other workers. Forbes (1935) describes plants in which the basal part is cylindrical and branched, resembling the thalli of some *Blastocladias*. Sparrow has described *Rhipidium americanum* showing examples of both the peltate thalli and the branched tree-like plants. Since the sporangial measurements are similar to those of plants described in other collections it is

likely that *Rhipidium americanum* is a species like *Blastocladia Pringsheimii* in which the thallus is extremely variable in size and shape.

PYTHIUM PROLIFERUM de Bary.

Pringsh. Jahrb. Wiss. Bot. 2, p. 182, 1860.

Saprophytic on twigs, in lake at University grounds; collected 5th April, 1935; mycelium delicate, hyphae of uniform diameter, varying from  $2-5\mu$ ; a few bud-like projections from the hyphae are sometimes found, but are not characteristic as in *Pythiomorpha gonapodioides*; sporangia developed in water cultures, spherical to pyriform in shape with a very long papilla; at maturity, they measure  $26-46\mu \times 20-32\mu$  (Fig. 6, F); proliferations occur, the secondary sporangia being formed inside the old one, or the hypha may grow through it and form the new sporangium at some distance further on; sporangia frequently function as conidia producing germ-tubes, but they also were observed to produce zoospores in the true *Pythium* fashion—that is, the protoplasm is

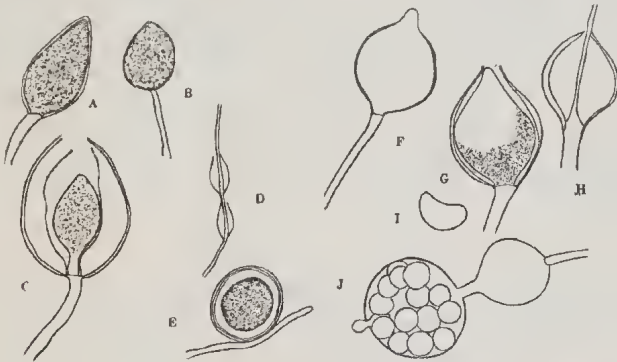


FIG. 6.—A-E, *Pythiomorpha gonapodioides* Petersen. F-H, *Pythium proliferum* de Bary. A, B, Young sporangia.  $\times 207$ . C, Proliferating sporangia.  $\times 207$ . D, Empty sporangia with the hypha growing through.  $\times 33$ . E, Oogonium with thick three-layered wall.  $\times 207$ . F, Sporangium with papilla. G, Proliferating sporangia. H, Empty sporangium through which hypha has grown. I, Zoospore. J, Sporangium with vesicle. All  $\times 207$ .

extended into a vesicle where the zoospores are differentiated (Fig. 6, J); in one case observed, 30 minutes elapsed from the time the vesicle was formed until the zoospores were set free; in the vesicle they are spherical, and, appear to escape at a thin point in the wall, they were constricted as they passed through, and assumed a reniform shape in the swimming stage, but settling down, they became spherical again; no sexual organs observed.

## PYTHIOMORPHA GONAPODIOIDES H. E. Petersen.

Bot. Tidsskr. 29, p. 391, figs. VI. and VII., 1909; and in Ann. Myc. 8, p. 528, figs. VI. and VII., 1910.

Saprophytic on rose hips in pond in Fitzroy Gardens, collected 20th July, 1935; on grapes, prunes, and rose hips in pond in Botanical Gardens, collected 23rd May, 1935; on oranges in McCallum's Creek, near Maryborough, collected 12th February, 1936. In the case of the grapes, the pond water was brought into the laboratory and baited with the fruit. Hyphae irregular in appearance, owing to the fact that a single hypha may vary in diameter from  $2-8\mu$ ; bud-like projections are frequently developed on the mycelium; sporangiophores of uniform diameter, slightly narrower than the ordinary hyphae; sporangia pyriform, papillate and proliferate frequently, the new sporangium formed within an old one or at some distance beyond it, and frequently a row of sporangia is developed (Fig. 6, D); range in size from  $40-70\mu \times 20-40\mu$ . Sporangia set free zoospores without the formation of a vesicle; zoospores—spherical,  $9-13\mu$  diameter, usually more than 20 per sporangium; sporangia were present on the mycelium on the fruit and hips when brought in; oogonia spherical,  $23-28\mu$  diameter, and when mature have a thick three-layered wall (Fig. 6, E); oospores yellowish in colour and  $20-22\mu$  diameter. Only one antheridium was noted, and this was clavate in shape and of diclinous origin.

This form agrees in all particulars with *Pythiomorpha gonapodioides* except in the size of the sporangia which are slightly larger in our form.

## BLASTOCLADIALES.

**Blastocladiaceae.**

GONAPODYA SILIQUAEFORMIS (Reinsch) Thaxter.

Bot. Gaz., 20: 480, pl. 31, figs. 6-10, 1895.

Saprophytic on rose hips and twigs in pond at University, and on rose hips again in pond at the Fitzroy Gardens; pustules on the fruit differed from those of *Blastocladia* in forming loose spreading mats of hyphae, in contrast to the short dense tufts of the *Blastocladias*; vegetative plant attached by scanty rhizoids, consists of hyphae more or less sparingly branched in the lower parts, but more copiously branched in the upper parts, giving a successively umbellate appearance; whole plant segmented, each constriction corresponding to a pseudo-septum formed by a deposit of cellulin; sometimes segmentation is almost entirely absent (Fig. 7, D), although the cellulin plugs may be present; in the basal parts, the segments are long and narrow but in the upper part short and rounded; sporangia,  $60-220 \times 15-35\mu$ , pod-shaped, frequently proliferating (Fig. 7, C, D), borne terminally on the hyphae or in umbels sometimes separated by a definite



constriction; zoospores numerous, hyaline with conspicuous nuclei and weak granular forward end, one backward moving cilium; sexual reproduction not observed.

GONAPODYA POLYMORPHA Thaxter.

Bot. Gaz., 20: 481, pl. 31, figs. 11-16, 1895.

Saprophytic on *Japonica* fruits in lake at Maryborough Gardens; vegetative plant consists of more slender hyphae in which segmentation is not pronounced, which give rise to tufted umbellate branches composed of oval or irregular segments; sporangia borne terminally on the segments, one to three arising from each segment, rather oval in shape, and truncate at the apex after dehiscence, size  $85-110\mu \times 35-45\mu$ ; sexual organs not observed. The habit of this plant strongly resembles that of

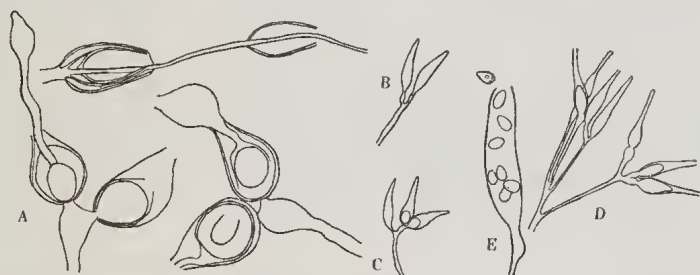


FIG. 7.—A, *Gonapodya polymorpha* Thaxter. Filaments with proliferating sporangia.  $\times 207$ . B-E, *Gonapodya siliquaeformis* Reinsch. B, Young sporangia.  $\times 33$ . C, D, Sporangia showing early stages in proliferation.  $\times 33$ . E, Zoosporangium with zoospores.  $\times 150$ .

*G. polymorpha*, but the size of the sporangia is definitely larger. However, the appearance is so similar to *G. polymorpha*, that it must be regarded as that species, in which the sporangia are larger, possibly, due to different environmental conditions.

BLASTOCLADIA (Reinsch) Emend.

Pringsh. Jahrb. Wiss. Bot. 2, p. 182, 1860.

Plant consists of large basal cell of very variable form, short and swollen, or long, cylindrical, branched or unbranched, the apices of the trunk or lobes often expanded; plant attached to substratum by rhizoids; filamentous hairs, simple or branched, often arise from the basal cell on its branches, and these hairs have a bulbous base; zoosporangia sessile on the basal cell, variable in size and shape; zoospores numerous, usually uniciliate, emerging through a terminal pore; resting spores sessile like the sporangia, usually oval or spherical in shape; antheridia have been observed in one species by Kanouse (1927), who concludes that the "resting-spores" should really be regarded as oogonia.



Up to the present, ten species of *Blastocladia* have been described, and a new species is given here, namely *Blastocladia aspergilloides* n.sp.

*Key to the Species.*

- |  |                                |
|--|--------------------------------|
| A. Basal cell swollen or cylindrical with swollen heads, branched or unbranched .. .. .  | B                              |
| Basal cell cylindrical, usually much branched, the apex of the thallus or its branches not swollen ..  | E                              |
| B. Basal cell globose, slightly narrowed towards base, sporangia 55-130 x 16-40 $\mu$ .. .. .  | <i>B. globosa</i>              |
| Basal cell cylindrical in the lower part, with swollen heads; thallus branched or unbranched ..  | C                              |
| C. Plants 140-260 $\mu$ , basal cell unbranched, sporangia long, narrow, cylindrical, 85-150 $\mu$ x 8-15 $\mu$ ..                                 | <i>B. aspergilloides</i> n.sp. |
| Plants usually larger, branched or unbranched, sporangia ovate or broadly cylindrical .. ..  | D                              |
| D. Sporangia proliferating .. ..   | <i>B. prolifera</i>            |
| Sporangia not proliferating ..   | <i>B. Pringsheimii</i>         |
| E. Plants tall, 600-950 $\mu$ x 20-45 $\mu$ , branched, hyaline; sporangia borne in a racemose or corymbose manner, 120-220 $\mu$ x 22-34 $\mu$ .. | <i>B. gracilis</i>             |
| Plants smaller, sporangia on the apex of the thallus or its branches ..  | F                              |
| F. Sporangia long, narrow, cylindrical, 60-210 $\mu$ x 8-25 $\mu$ .. ..  | <i>B. augusta</i>              |
| Sporangia broadly cylindrical or oval  | G                              |
| G. Plant very hyaline, sporangia oval, 27-40 $\mu$ x 7-13 $\mu$ , not proliferating  | <i>B. ramosa</i>               |
| Plant dark in colour, sporangia broadly cylindrical, not narrowed at base, proliferating, 80-140 $\mu$ x 18-35 $\mu$ .. .. .                       | <i>B. prolifera</i>            |

BLASTOCLADIA PRINGSHEIMII Reinsch.

Jahrb. Wiss. Bot. 11: 298, 1878.

Emend. Thaxter, Bot. Gaz. 21: 51, 1896.

Saprophytic on rose hips, lake at University, 5th April, 1935, Botanic Gardens, 23rd April, 1935; Fitzroy Gardens, 20th July, 1935; on banana, Yarra River, Rudder Grange, 10th November,

1935; on apples, *Japonica* fruits, winter-cherry fruits, lake at Maryborough Gardens, 13th February, 1936; *Cotoneaster* berries, *Japonica* fruits, McCallum's Creek, Maryborough, 12th February, 1936; on apples, Barham River, Apollo Bay, 1st June, 1936.

This form is an extremely common saprophyte on any decaying fruits, but was never found on twigs of any kind; the pustules of *Blastocladia Pringsheimii* were dense, tufted, up to 1 mm. in diameter, and yellowish white in colour. There were usually a large number of individuals in a pustule, and although occasionally a pustule is composed entirely of plants of the one species, usually *B. Pringsheimii* was associated with other forms, e.g., *Rhipidium*, or other *Blastocladia* sp., but not with the filamentous fungi, e.g., *Saprolegnia*, *Achlya*.

Plant consists of a large basal cell attached to the substratum by rhizoids, and very variable in size and shape; figure 8 shows the variations in the thallus of *B. Pringsheimii* from material obtained from different sources; basal cell may be fairly short, unbranched and swollen towards the apex, or long cylindrical, branched or unbranched, the distal part of the trunk or of the lobes being rather swollen; on the expanded region the sessile sporangia are borne, together with filamentous hairs, simple or branched and with a bulbous base; sporangia more or less long,



FIG. 8.—*Blastocladia Pringsheimii* Reinsch. Plants showing varying size and shape of basal cell and sporangia.  $\times 25$ .

cylindrical, ranging in size from  $70\text{--}280\mu \times 14\text{--}70\mu$  over a large number of plants; zoospores numerous,  $12\text{--}15\mu$  in diameter, escaping directly through the terminal pore; the formation of a vesicle described by Von Minden (1916) and Sparrow (1932) was not observed; zoospore discharge seems to be largely influenced by external conditions, as in most of the sporangia observed, the zoospores did not escape but disintegrated within

the sporangium; resting spores frequently found, and always associated with the sporangia, oval or spherical, thick-walled, punctate and  $40-99\mu \times 30-50\mu$ .

As suggested by Sparrow (1936), *B. Pringsheimii* appears to be a very variable form, both in the nature of the thallus, and in the size of the sporangia. In practically each locality, whence this form was obtained, the habit varied, as also did the range in sporangial size, giving from all the plants examined, a wide range of  $70-280\mu \times 40-70\mu$ , although in individual plants the range was not of this order. From the measurements of the length and breadth of the sporangia in 265 individuals, frequency

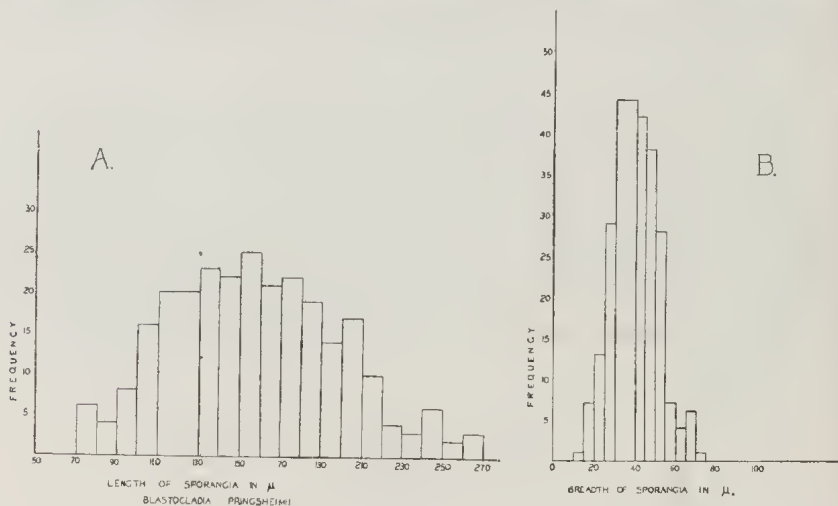


FIG. 9.—*Blastocladia Pringsheimii*. Frequency diagrams to illustrate variation in length (A) and breadth (B) of sporangia.

column diagrams have been prepared and from these the maximum frequency in length and breadth can be noted. In the length diagram, the lengths are arranged in classes with an interval of 10, e.g., 70-79.9, 80-89.9, etc. Thus there are 25 individuals (sporangia) with a length between 150 and 159.9, which class shows the greatest frequency, 21 individuals with length between 160 and 169.9, etc. In the diagram illustrating breadth (Fig. 9, B) a measurement which is not as variable as the length, and hence shows a greater frequency in the classes (since the same number of individuals were measured in both cases) the breadths are arranged in classes with an interval of 5, e.g., 10-14.9, 15-19.9, etc. This method was used here instead of classes with an interval of 10, only for greater convenience in preparing the diagram, owing to the greater frequencies shown in the classes, e.g., between 30-34.9, there is a frequency of 44, between 35-39.9, a frequency of 42 also, hence between 30-39.9 a frequency of 86 (which would be difficult to express with the scale in use), which is the maximum frequency. Although these

forms appear widely different in size, habit, etc., there does not at present seem to be sufficient justification to separate them as other species, particularly on the basis of measurements. Size is a very variable character, particularly when studied over a large number of individuals, and may be influenced by external conditions, e.g., amount of food material present, etc.

*BLASTOCLADIA PROLIFERA* von Minden.

Kryptogamenfl. Mark Brandenburg, 5: 606, 1912.

Saprophytic on rose hips, lake at University, collected 5th April, 1935; Saprophytic on apples and *Japonica* fruits, lake at Maryborough, collected 13th February, 1936; this species was found in pustules and was sometimes associated with *Blastocladia Pringsheimii* or with *Gonapodya*. In the first collection obtained of this form, on rose hips, the plants were a dark bluish-black colour and this was also characteristic of the *B. Pringsheimii* plants associated with it. In a later collection from a different locality, the plants of *B. prolifera* were not striking in colour at all, only tinged with brown, and *B. Pringsheimii* when found in other parts, and on rose hips again, did not have this bluish-black colour, although plants of the latter are often dark brown in colour. The cause of this unusual colour is not known.

Plant attached to substratum by rhizoids; basal cell cylindrical in the lower part, about  $150-300\mu \times 50-70\mu$  but irregularly and copiously branched in the upper parts, the branches often only  $10\mu$  in diameter; sterile hairs were seldom present; sporangia sessile on the branches, cylindrical, often curved, rounded at the apex; but truncate at the base,  $80-140\mu \times 18-35\mu$ , proliferating by successive sporangia formed inside the old ones; resting spores

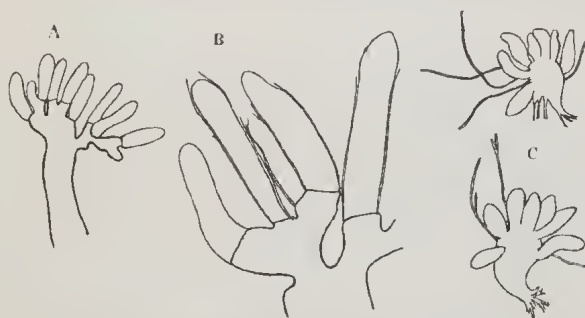


FIG. 10.—A, B, *Blastocladia prolifera* von Minden. A, Young plant showing irregular branching and sessile sporangia.  $\times 100$ . B, Portion of thallus showing proliferating sporangia.  $\times 270$ . C, *Blastocladia globosa* Kanouse. Plants bearing sporangia and sterile hairs.  $\times 100$ .

not observed: the plants, generally, are smaller than those of *B. Pringsheimii*, and the lobes or branches are not swollen at the apex as in *B. Pringsheimii* except in one or two cases.



Sparrow (1936) figures plants of *B. prolifera* in which the heads are definitely rounded. In the plants examined here the sporangia were often so densely crowded around the top of the plant, that the nature of the sporangia could not be seen, but it gave the appearance of a head similar to that of *B. Pringsheimii*. When the plants were dissected the crowded, irregular branching were observed. Proliferating sporangia were abundant in the older plants.

BLASTOCLADIA GRACILIS Kanouse.

Amer. Jour. Bot., 14, p. 300, pl. 33, figs. 14-16, 1927.

BLASTOCLADIA RAMOSA var. LUXURIANS Kanouse.

Michigan Acad. Sci. Arts and Letters: 105, pl. 1, fig. 1.

Saprophytic on apples, rose hips, and banana. Yarra River at Rudder Grange, collected 10th November, 1935. This species occurred in the same pustules as *Blastocladia* n.sp., *Blastocladia gracilis*, and *Gonapodya siliquaeformis*. Plant attached to substratum by weakly-developed rhizoids, whole plant 600-950 $\mu$  in length; basal cell cylindrical, slender, about 20-45 $\mu$  in diameter, branched in a racemose to sub-dichotomous manner, hyaline, smooth, wall thin—2-4 $\mu$ . Sterile hairs with bulbous base noted on some plants (Plate X., 3); zoosporangia borne in a racemose or corymbose fashion, long cylindrical, 120-220 $\mu$  x 23-34 $\mu$  (Fig. 11, A); resting spores usually terminal on the branches, oval to spherical with a truncate base, 45-60 $\mu$  x 25-40 $\mu$  (Fig. 11, B). This plant is very similar to the species described by Kanouse, except in the slightly larger size of the sporangia and the presence of sterile hairs on some plants, also the plants are sometimes more branched than Kanouse suggests—a feature also observed by Lund (1934).

BLASTOCLADIA RAMOSA Thaxter.

Bot. Gaz. 21, 50, pl. 3, figs. 14-16, 1896.

Saprophytic on banana fruits, Yarra River at Rudder Grange, collected 10th November, 1935; this fungus occurred in pustules associated with *Blastocladia gracilis*; plant attached to substratum by poorly developed rhizoids, whole plant 500-700 $\mu$  in length; basal cell cylindrical, 15-33 $\mu$  in diameter, copiously and irregularly branched in the upper parts, the finer branches which bear the reproductive organs terminally, having a diameter of only 5-14 $\mu$ ; wall thin, smooth, hyaline, the whole plant having a very delicate appearance; zoosporangia oval, slightly narrowed towards the base, 27-40 $\mu$  x 7-13 $\mu$ ; resting spores bluntly rounded at the apex, narrowing towards the base, 18-25 $\mu$  x 11-13 $\mu$  (Fig. 11, I).

The plants seem to be taller than those described by Thaxter, but from its delicate appearance, and small size of the sporangia and resting spores, it is unmistakably *B. ramosa*. The size of the



sporangia and resting spores agrees fairly well with those of Thaxter, 1896A) and of Sparrow (1932), but differs greatly from those of another collection described by Sparrow recently, in which the reproductive organs are much larger.

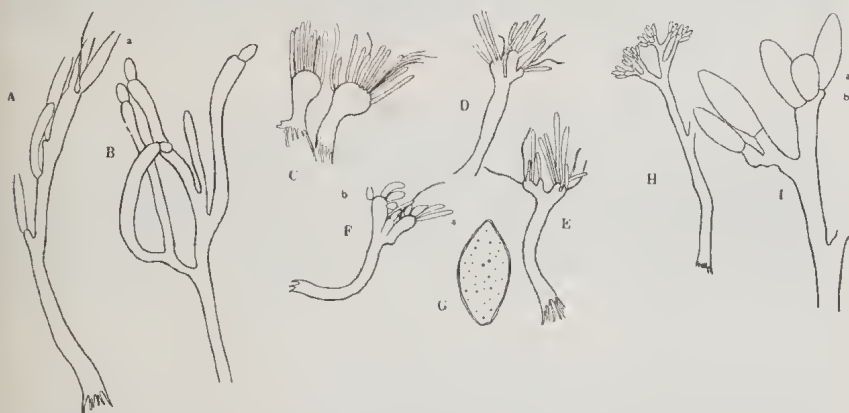


FIG. 11.—A, B, *Blastocladia gracilis*. C, *Blastocladia aspergilloides* n. sp. D-G, *Blastocladia augusta* Lund. H, I, *Blastocladia ramosa* Thaxter. A, Plants with sporangia (a)  $\times 30$ . B, Plants with resting spores (b)  $\times 30$ . C, Plants with sporangia  $\times 30$ . D, E, F, Plants bearing sporangia (a) and resting spores (b)  $\times 30$ . G, Resting spore.  $\times 205$ . H, Portion of plant with sporangia.  $\times 90$ . I, Part of plant showing sporangia (a) and resting spores (b)  $\times 205$ .

# BLASTOCLADIA AUGUSTA A. Lund.

Memoires de l'Acad. Roy. des Sc. and Lett. de Danemark,  
Copenhagen, p. 44, fig. 21, 1934.

Saprophytic on rose hips, lake at University, collected 5th April, 1935; on rose hips in lake at Botanic Gardens, collected 23rd May, 1935; the small whitish pustules in which this form was found consisted either entirely of this species or occasionally contained a few plants of *B. Pringsheimii*.

Plant attached to substratum by thin branching rhizoids, often copiously developed; whole plant very delicate and hyaline, but in a few plants observed, the contents were quite brownish; plants 160–500 $\mu$  high; basal cell slender, cylindrical, 10–35 $\mu$  in diameter and usually branched in the upper parts—occasionally unbranched plants are obtained. The tips of the branches on which the reproductive organs are borne are not swollen and globose as in *B. Pringsheimii*, although sometimes they gradually increase in diameter towards the tip. Sterile hairs usually present (Plate X., 5, Figs. 11 D–F); sporangia long cylindrical, narrow, 60–210 $\mu$   $\times$  8–25 $\mu$ ; resting spores oval, light coloured, usually narrowed towards the tip; apex of spores rounded or sometimes beaked (Fig. 11, G); resting spores thin-walled, and sometimes a suggestion of a pitted inner wall is obtained; size 25–45 $\mu$   $\times$  16–26 $\mu$ .

In their light colour and thin outer wall, these spores resemble those of *B. ramosa*, which, according to Thaxter (1896A), may properly be spoken of as conidia. Although most of the plants

showed only the sporangial stage, a few were obtained in which resting spores were present, and these have not been observed previously. They appear to resemble those described for *B. rostrata* (Minden 1912) but the latter, although not examined by the author, appears to be a larger plant, differing in habit, with fusiform sporangia, in contrast to the narrow, cylindrical ones of this species.

BLASTOCLADIA GLOBOSA Kanouse.

Amer. Jour. of Botany, vol. XIV., p. 298, pl. XXXII., figs. 1-4, 1927.

Saprophytic on berries of *Solanum pseudo-capsicum*, lake at Maryborough, collected 13th February, 1936; plants occurred in very small, dense, whitish pustules, sometimes associated with *Gonapodya siliquaeformis* but more often alone; plant attached to substratum by a few rhizoids, not as extensively developed as in *B. Pringsheimii* (Fig. 10, C); basal cell globose to sub-globose usually narrowed towards base, sometimes lobed, the lobes being very swollen; plants 120–200 $\mu$  high and up to 200 $\mu$  in diameter, the narrow part from which the rhizoids develop having a diameter of 30–50 $\mu$ ; wall fairly thick and laminate, protoplasm dark brownish. Sterile hairs usually present, simple or branched; sporangia sessile, broadly cylindrical, 55–130 $\mu$  x 16–40 $\mu$  (Plate X., 2); resting spores oval to spherical, 25–35 x 27–32 $\mu$  and are dark with a thick pitted wall.

The antheridial filaments described by Kanouse were not observed. The habit of this plant strongly suggests *B. globosa*, but the size of the sporangia, and in a greater degree, that of the resting spores, is smaller than those described by Kanouse, and also by Sparrow (1936).

BLASTOCLADIA ASPERGILLOIDES n.sp.

Saprophytic on rose hips, lake at University, collected 5th April, 1935; on apples at Yarra River, Rudder Grange, collected 10th November, 1935; plants occurred in small, whitish pustules, either alone or associated with *B. gracilis*.

Plant attached to substratum by means of a few fairly stout rhizoids—up to 5 $\mu$  in diameter; plant consists of a single cell, cylindrical in the lower part 25–45 $\mu$  in diameter, but expanded at the apex to form a swollen head—60–85 $\mu$  in diameter (Plate X., 1, 2, Fig. 11 C); branched forms were not observed; plants 140–200 $\mu$  high, dark in colour due to dark brown protoplasm, wall of basal cell fairly thick, 3.5–5 $\mu$ ; sterile hairs usually present, only 1–2 $\mu$  in diameter; sporangia long, narrow, cylindrical, arising from the swollen head, 85–150 x 8–15 $\mu$ . Zoospores emerge through a terminal opening; resting spores not observed.

The species is characterized by its unbranched basal cell with a swollen head bearing long thin sporangia, the whole plant having a dark brown colour. The sporangia in form and size

are similar to those of *B. augusta* Lund., although slightly narrower, but the latter species has a branched basal cell usually, the branches not being swollen at the apex, and the whole plant is delicate and hyaline in appearance. Both species were found on the same fruit but not in the same pustule.

*Latin description* :—

BLASTOCLADIA ASPERGILLOIDES (n.sp.).

Planta paucis filamentis rhizoideis crassis substrato affixa; cellula basali simplici, parte inferiore cylindrica diametro  $25-45\mu$ , capite inflato, diametro  $60-85\mu$ ; altitudine  $140-260\mu$ , colore atrofusco, muris cellulae  $3.5-5\mu$  crassis. Adsunt plerumque capilli steriles diametro  $1-2\mu$ . Sporangia longa angusta cylindrica  $85-150\mu \times 8-15\mu$ . Oosporae ignotae.

### Summary.

1. Aquatic fungi have been collected from different localities. The methods of collection were those recommended by other workers—placing traps containing baits in the ponds or streams, although additional baits have been used.

After four to six weeks, the baits were brought into the laboratory, examined, and when possible, pure cultures of the fungi were obtained.

2. Twenty species were examined, only one of which, namely, *Saprolegnia ferax*, has previously been described from Australia.

3. An account is given of the systematic and physiological characteristics of these species, including experiments regarding the formation of the sexual organs in various media.

4. The species recorded are :—

*Saprolegnia ferax* (Gruith) Thuret.,

*Achlya conspicua* Coker,

*Achlya americana* var. *megasperma* var. nov.,

*Achlya oblongata* de Bary,

*Achlya* sp. ?,

*Dictyuchus* sp.,

*Dictyuchus monosporus* Leitgeb.,

*Pythium proliferum* de Bary,

*Pythiomorpha gonapodioides* H. E. Petersen,

*Sapromyces Reinschii* (Schroeter) Fritsch.,

*Rhipidium americanum* Thaxter,

*Gonapodya siliquaeformis* (Reinsch.) Thaxter,

*Gonapodya polymorpha* Thaxter,

*Blastocladia Pringsheimii* Reinsch,

*Blastocladia prolifera* Von Minden,  
*Blastocladia gracilis* Kanouse,  
*Blastocladia ramosa* Thaxter,  
*Blastocladia angusta* A. Lund,  
*Blastocladia globosa* Kanouse,  
*Blastocladia aspergilloides* n.sp.

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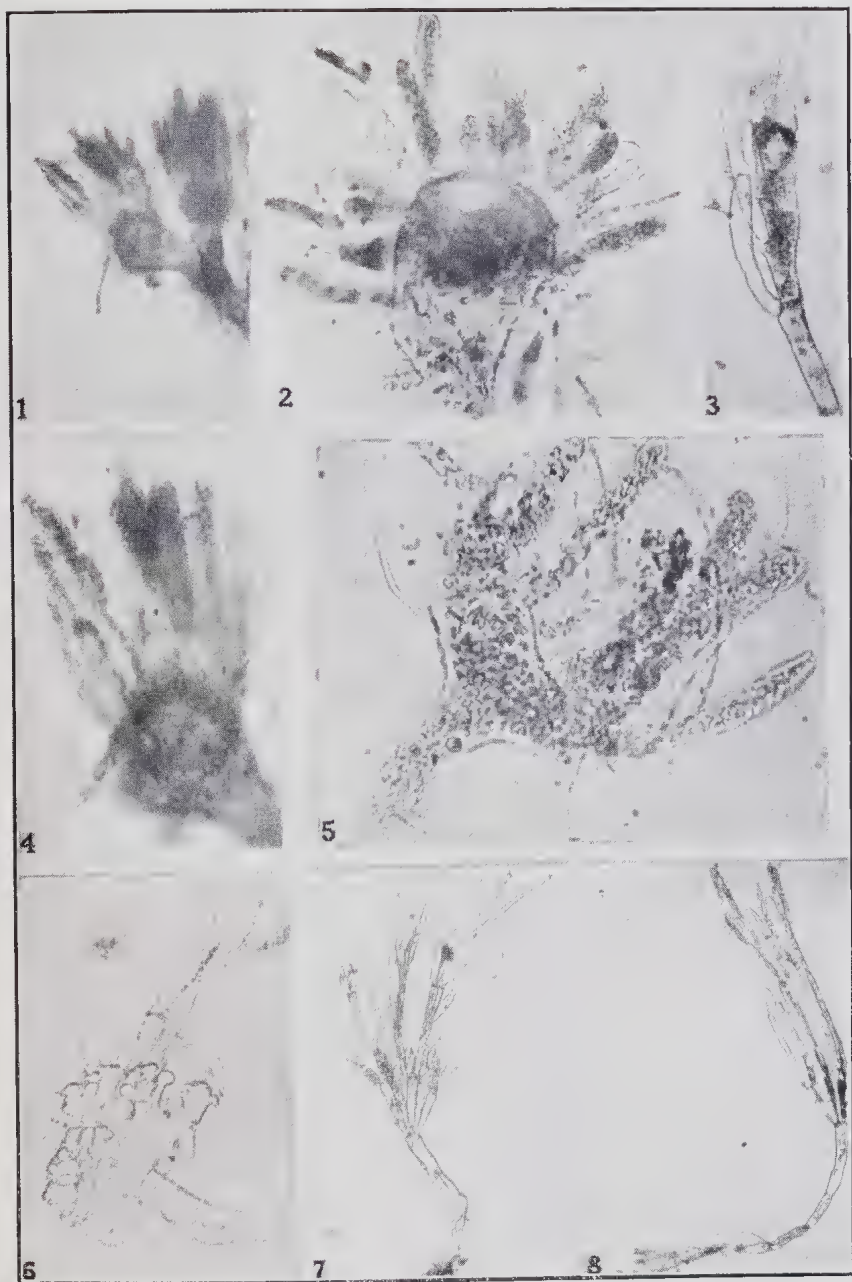


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### Explanation of Plates.

- FIG. 1.—*Blastocladia aspergilloides* n. sp. Two plants with sporangia.  $\times 150$ .
- FIG. 2.—*Blastocladia globosa* Kanouse. Plant showing swollen basal-cell with rhizoidal system and sporangia.  $\times 450$ .
- FIG. 3.—*Blastocladia gracilis* Kanouse. Thallus with sporangia.  $\times 100$ .
- FIG. 4.—*Blastocladia aspergilloides* n. sp. Apex of thallus showing swollen head with sporangia.  $\times 620$ .
- FIG. 5.—*Blastocladia angusta* Lund. Upper part of thallus showing branches—not swollen at the apex.  $\times 620$ .
- FIG. 6.—*Rhipidium americanum* Thaxter. Thallus bearing filaments.  $\times 450$ .
- FIGS. 7, 8.—*Sapromyces Reinschii* (Schröeter) Fritsch. Plants with sporangia.  $\times 100$ .

\*These papers were not obtainable for reference.



Aquatic Phycomycetes.



[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. II., 1937.]

ART. XV.—On *Saprolegnia terrestris* sp. nov., with some Preliminary Observations on Victorian Soil *Saprolegniales*.

By ISABEL COOKSON, D.Sc.

[Read 12th November, 1936; issued separately 19th July, 1937.]

Amongst the several Phycomycetes that have been isolated from soil samples taken from the fern gullies of the Dandenong Ranges near Melbourne, a characteristic form of *Saprolegnia* has been present. This form has been cultured for some considerable period on hemp seed pieces in sterilized tap water and has also been isolated several times from fresh soil samples. Throughout it has maintained certain constant characteristics which appear to distinguish it from any previously described species. The fact that considerable variations in both habit and form occur in cultures of the so-called species of *Saprolegnia* and *Achlya* has been recognized and considered. Nevertheless the conclusion reached after careful observation is that this form which has been isolated, and is to be described below, is an hitherto unrecorded species of *Saprolegnia*. It will be known as *Saprolegnia terrestris*.

*S. terrestris* grows well on hemp seed pieces in sterilized tap water, and in some such cultures fertile oogonia develop abundantly without special treatment. Frequently, however, it has been necessary to induce the formation of oogonia by the method suggested by Couch (1932). In such cases young cultures on hemp seed were grown for three days in a 2 per cent. solution of peptone; they were then washed in tap water, and subsequently grown in sterilized tap water for about seven days. After such treatment large numbers of oogonia were usually produced. The following diagnosis has been made from hemp seed cultures with or without growth for a period in 2 per cent. peptone solution.

*Diagnosis*.—Growth on hemp seed about 0.5–1 cm. long, mycelial mat thick. Hyphae slender, up to  $48\mu$  broad at the base. Sporangia abundant, very variable in shape, typically cylindrical or clavate  $16\text{--}48\mu$  broad,  $60\text{--}400\mu$  long, frequently almost spherical sometimes irregular and contorted, opening apically by a more or less prominent mouth. Primary sporangia terminal; secondary sporangia develop either by internal proliferation or by the delimitation of a segment behind a discharged sporangium and the outgrowth from this segment of a sporangium; occasionally secondary sporangia develop in a truly cymose manner. Spores diplanetic about  $10.5\mu$  when encysted. Gemmae usually not abundant, cylindrical, pyriform, or irregular in shape. Oogonia borne terminally or laterally on straight stalks which are as long as, or considerably longer than, the diameter of the



FIG. 1.—*Saprolegnia terrestris* sp. nov. Types of sporangia.  $\times 125$ . Gemmae.  $\times 125$ .

oogonium, sometimes intercalary; typically spherical, sometimes with a neck, or, when developed within an empty sporangium, cylindrical, occasionally with a short apiculus,  $30-87.5\mu$  in diameter, average  $61\mu$ . Oogonial wall usually yellow, frequently unpitted but in some cultures with well defined though not conspicuous pits. An upgrowth from the basal wall of the oogonium is frequently present, and an irregular internal thickening of the oogonial wall is sometimes met with in old hemp seed cultures. Oospores  $1-10$  usually  $2-6$ ,  $20-37\mu$  in diameter, average  $29\mu$ , dark brown when immature, later becoming yellowish; eccentric in sense that the peripheral sheath of oil drops does not completely surround the protoplasm, or subcentric. Antheridia present on all oogonia, typically one, sometimes two or three; antheridial branches androgynous, usually simple, but sometimes slightly branched, typically arising from the oogonial stalk immediately behind the oogonium but occasionally developing from the same hypha as the oogonium; antheridia clavate attached by their sides to the oogonium, becoming inconspicuous; antheridial tubes large and conspicuous.

In considering the affinities of *S. terrestris*, the structure of the oospore is of considerable importance. This, in *S. terrestris*, has an unusual form and one that is almost unique for the genus *Saprolegnia*. In a large number of the mature spores the spherical protoplasmic body is incompletely surrounded by fat



droplets, these being entirely lacking on part of one side (Fig. 2, D, G, H, and Plate XI., figs. 6, 9, 10, 15). Eggs with a similar construction occur, according to Coker (1923), in *Achlya oblongata* de Bary, and in *Aplanes Treleaseanus* (Humphrey) Coker (1927). In both cases they have been described as subcentric. I propose to distinguish, by the use of the term "eccentric," the eggs of *S. terrestris* from the typical subcentric type in which the protoplasm is surrounded by one layer of oil drops on one side and two or three on the other. Frequently

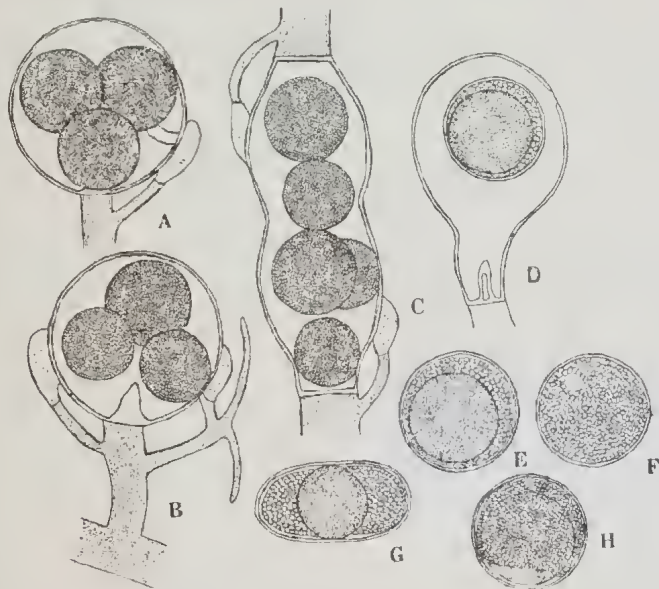


FIG. 2.—*Saprolegnia terrestris* sp. nov. (a) A spherical oogonium with antheridium showing fertilization tube.  $\times 285$ ; (b) Oogonium showing basal ingrowth.  $\times 285$ ; (c) An intercalary oogonium.  $\times 285$ ; (d) An oogonium containing a single eccentric oospore.  $\times 440$ ; (e) An apparently subcentric oospore in optical section.  $\times 440$ ; (f) The same oospore focussed to show that the peripheral sheath of oil drops is incomplete.  $\times 440$ ; (g) An elliptical oospore with two lunate masses of oil drops.  $\times 440$ ; (h) an eccentric oospore.  $\times 440$ .

eggs of *S. terrestris* when viewed in optical section appear to be subcentric (Fig. 2, E). However, when the focus is changed a small clear area from which oil drops are absent will usually be seen at some point in the peripheral sheath (plate XI., Fig. 7; Fig. 2, F). In these eggs also the protoplasm is incompletely invested. In addition a small number of truly subcentric eggs occur in most cultures. It will be seen therefore that the oospores of *S. terrestris* range from the eccentric to the subcentric condition.

The only species of *Saprolegnia* in which the oospores are said to be eccentric is the plant isolated and described by Von Minden (1912), and referred by him to Cornu's inadequately described species *S. spiralis* (1872). In Coker's translation of

Von Minden's description on page 71 of "The Saprolegniaceae," the eggs are described as follows:—"Eggs mostly 1-2 seldom 3 or even 4, smooth, spherical or when several more or less elongated, at maturity with one or many mostly lateral fat drops and therefore more or less plainly eccentric." As no figures are given, it is impossible to say whether or not their structure agrees exactly with that of the eggs of *S. terrestris*, but Von Minden's statement that the eggs of his plant are "more or less plainly eccentric" necessitates a comparison of the two forms.

Apart from the spore characteristics previously mentioned, there are several morphological features in which the two plants agree exactly. The most important are the mode of development of the secondary sporangia, either by proliferation or "cymose" development; the position of the oogonia, either lateral, terminal, or intercalary; the occasional presence of a blunt extension of the tip of the oogonium, the inconspicuous pitting, or entire absence of pits from the oogonial walls; the size of the oogonia and the approximation in size of the oospores; the androgynous antheridial branches, which develop either from the stalk of the oogonium or from the main hyphae and which become inconspicuous.

Several differences, however, are evident. The secondary sporangia are always abundantly developed in *S. terrestris*, whereas they are reported to be few in number in *S. spiralis*. More important is the fact that the oogonial stalks are not bent or spirally coiled as in *S. spiralis*. Further, the oogonia of the latter are usually "elliptic or ovate," whereas in *S. terrestris* they are typically spherical. There is no mention in Von Minden's description of the colouration of the oogonial walls or of the in-growth from the basal wall of the oogonium, both of which are usual features of *S. terrestris*. The antheridial branches are simpler in the latter, and are never "numerous and much branched" as in *S. spiralis*; further, they only rarely develop away from the oogonial stalk in *S. terrestris*. The number of eggs is on the average higher in the latter, being usually 2-4, and as high as 10, and the eggs are slightly larger, with an average of  $29\mu$  as against an average of  $26\mu$  in *S. spiralis*. It is because these differences exist that I have decided to regard the two plants as specifically distinct. I have also been influenced in making this decision by the rather questionable systematic position of Von Minden's plant, and by the doubt that exists, in the absence of figures, as to the detailed structure of its oospores.

Of the other described species of *Saprolegnia*, those with sub-centric spores, namely, *S. megasperma* Coker and *S. asterophora* de Bary are of interest. Both, however, are quite distinct from *S. terrestris* in several important characters. The possibility that *S. retorta* Horn (1904) is synonymous with *S. spiralis* Cornu as suggested by Von Minden is not important in this discussion since *S. terrestris* differs from Horn's plant in such constant

features as the size and structure of the oospores, the absence of spirally coiled oogonial stalks as well as in the copious production of sporangia.

Amongst the centric spored species of *Saprolegnia* the one to which *S. terrestris* approaches most nearly is *S. littoralis* Coker. The characters in which the two forms agree are those which they share in common with Von Minden's plant described as *S. spiralis* Cornu which Coker thinks may possibly be identical with *S. littoralis*. *S. terrestris*, however, is distinct from *S. littoralis* in the less abundant and simpler antheridial branches, in the presence of an in-growth from the basal wall of the oogonium as well as in the structure of the oospores.

### Some Preliminary Observations on Victorian Soil Saprolegniales.

The presence in soil of the so-called aquatic fungi was demonstrated by Harvey in 1925. Since then the work of Coker (1926, 1927), Couch (1927), and Harvey (1930) in America, of Nagai (1931) in Japan, and of Cook and Morgan (1934) in Wales has shown that many members of Saprolegniales are normal components of the soil flora. With a view to ascertaining the particular forms that are present in Australian soils some preliminary isolations from three distinct types of soil have been made. The investigation, which, it is proposed, shall include a study of the ecological distribution and seasonal occurrence of the Saprolegniaceous forms, is as yet in its preliminary stages. The number of isolations that have been made is comparatively small and the list of species given below is consequently incomplete. No conclusions as to the distribution of the individual species can be drawn from it.

The method adopted for the isolation from soil samples has been that suggested by Harvey (1925). Soil was taken to a depth of 3 inches and placed in crystallizing dishes. It was covered with sterilized tap water and when the water had cleared, boiled pieces of hemp seed were sown on the surface of the soil. Pure cultures on either corn-meal agar or malt agar were obtained from the fungal growths that appeared on the hemp seed and from the agar cultures pure hemp seed colonies were secured of the individual types isolated. The specified identification has been based throughout on such pure hemp seed cultures.

In this preliminary work soil has been taken from three localities:—

Locality A.—Bush soil of a clay character which supports an endemic flora, at Ringwood near Melbourne. Rainfall 30 inches but subject to severe periods of drought during the summer months.

Locality B.—Rich humus soil from fern gullies in the Dandenong Ranges near Melbourne. Rainfall approximately 40 inches. Soil moist all the year round except perhaps in unusually dry seasons.

Locality C.—Cultivated soil from the System Garden of the University of Melbourne. Rainfall 26 inches. Artificially watered during the summer.

### Locality A.—Ringwood.

*ACHLYA* cf. *IMPERFECTA* Coker in "The Saprolegniaceae" 1923.

A species of *Achlya* has been isolated which appears to be nearer to *A. imperfecta* Coker than to any other species of *Achlya*. The chief variation from the type is in the size of the oospores, which are considerably larger in the Victorian plant.

*Diagnosis*.—Sporangia and spores as in the species. Oogonia spherical, occasionally with an apiculus,  $50-90\mu$  in diameter, racemosely borne on long or short stalks; oogonial wall smooth and frequently unpitted, sometimes showing several inconspicuous pits, in-growth from the basal wall frequently present. Oospores eccentric with a single large oil drop, 1-10 in an oogonium,  $22.5-32.5\mu$  in diameter, average  $26.5\mu$  many degenerating. Antheridial branches androgynous and declinous, but more frequently androgynous, sometimes arising from the oogonial stalk, frequently much branched and occasionally almost completely investing the oogonium.

Lund (1934) has identified a plant from Danish soil as *A. imperfecta* Coker which differs from the type in the greater size of the oospores,  $22.5-27.5\mu$  as against  $17-23\mu$ , and in the more numerous pits in the oogonial wall. The Victorian plant approaches Lund's form in the size of the eggs, but differs from it and agrees with the type in the infrequent pitting of the oogonial wall. It is felt that further observations are necessary before a more definite and satisfactory statement as to the identification of the Victorian species can be made.

*ACHLYA* *APICULATA* de Bary, Bot. Zeit. xlvii., p. 635, 1888.

In general agreement with the type. The oogonial apiculus was seldom seen. In old hemp seed cultures the irregular internal thickening of the oogonial wall mentioned by Coker and Couch in their descriptions of *A. apiculata* var. *prolifera* was observed. Oogonia  $45-125\mu$  in diameter. Oospores  $32-47.5\mu$ .

### Locality B.—Dandenong Ranges.

*SAPROLEGNIA TERRESTRIS* sp. nov., described above.

From fern gullies at Upper Ferntree Gully, Kallista, and Kalorama.



SAPROLEGNIA MAGASPERMA Coker, "The Saprolegniaceae," 1923.

Similar to the type. Oogonia 35–70 $\mu$ . Oospores 27–50 $\mu$ , single in 90 per cent. of the oogonia. From Upper Ferntree Gully. This species has not been previously recorded from the soil.

ACHLYA RACEMOSA Hilderbrand, Jahrb. f. wiss. Bot. 6, p. 249, 1867.

Identical with the type. Oospores 22.5–27.5 $\mu$ . From Kallista.

ACHLYA APICULATA de Bary.

Similar to cultures obtained from Locality A.

ACHLYA cf. IMPERFECTA as from Locality A.

THRAUSTOTHECA CLAVATA (de Bary) Humphrey, Trans. Am. Phil. Soc. xvii., p. 131, 1892 (1893).

In exact agreement with the type.

### Locality C.—University Grounds.

SAPROLEGNIA ANISOSPORA de Bary, Bot. Zeit. xlv., p. 619, 1888.

General characters are in agreement with the type. Large zoospores ranged in diameter from 15–20 $\mu$ , the small ones were 10 $\mu$ . In all cultures the large zoospores greatly exceeded the small ones in numbers. This was not the case in Coker's material. Contrary also to the experience of both Coker (1923) and Nagai (1931), the oogonia were difficult to obtain. Small oogonia developed when young hemp seed cultures were grown in 2 per cent. peptone solution, and subsequently in sterilized tap water. Both oogonia and oospores were slightly smaller than is usual, the oogonia ranging from 25–45 $\mu$  and the oospores from 11–25 $\mu$ , but this may have been due to the means by which their formation was induced. Not previously recorded from soil.

SAPROLEGNIA TERRESTRIS n.sp.

In exact agreement with material from Locality B.

ACHLYA CAROLINIANA Coker, Bot. Gazette, l., p. 381, 1910, and Coker and Braxton, J. Elisha Mitchell Sci. Soc., vol. xlii., p. 139, 1926.

This species was obtained from each isolation made, characters agree with those of type. Oogonia 20–50 $\mu$ . Oospores 14–25 $\mu$ , up to 6 per oogonium. Antheridial branches declinous or androgynous disappearing with age of the culture.

ISOACHLYA UNISPORA Coker and Couch in "The Saprolegniaceae," 1923.

Characters in agreement with the type with the exception that sporangia were abundant in all cultures and were developed either within or without the empty sporangium not entirely without it as in Coker's material. Oogonia 27.5–45 $\mu$ . Oospores 22.5–42.5 $\mu$ .



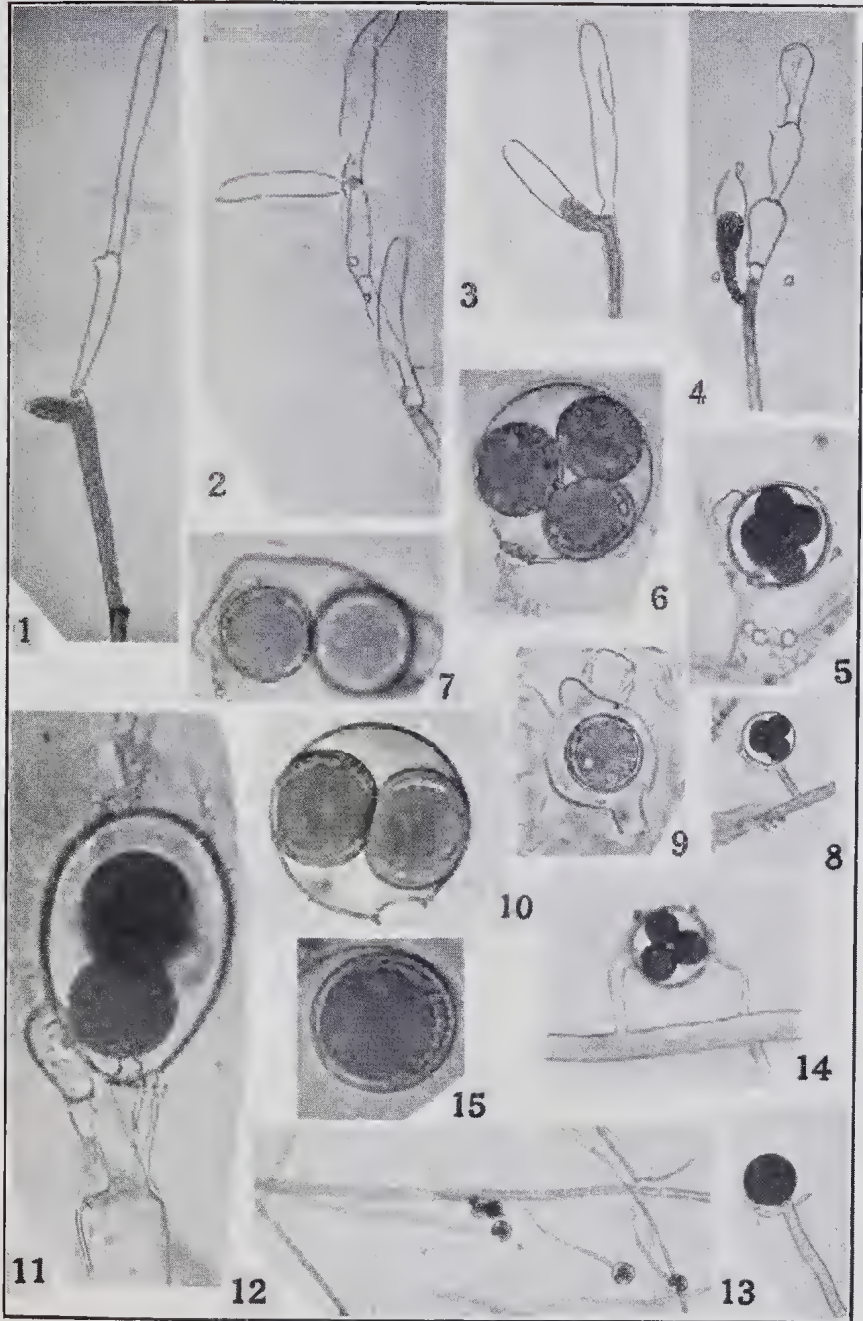
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## Explanation of Plate.

All figures are of *Saprolegnia terrestris* n. sp. Photographs were taken of living material in water and prints were made from unretouched negatives.

- Figs. 1-4. Show the mode of formation and variation in shape of sporangia.  $\times 120$ .
- Fig. 5. An oogonium showing typical origin of antheridial branch and the presence of a pit in the oogonial wall.  $\times 160$ .
- Fig. 6. An oogonium showing two eccentric oospores.  $\times 490$ .
- Fig. 7. Two oospores of a cylindrical oogonium; the left hand egg shows subcentric structure, the right hand one is focussed to show the incompleteness of the peripheral sheath of oil drops.  $\times 490$ .
- Fig. 8. A typical oogonium and antheridium.  $\times 120$ .
- Fig. 9. An oogonium with a neck, a terminal apiculus and one eccentric oospore.  $\times 360$ .
- Fig. 10. A spherical oogonium with two elliptical oospores in which the oil drops are restricted to two lunate areas.  $\times 490$ .
- Fig. 11. A cylindrical oogonium within an empty sporangium, showing an antheridial branch and an upgrowth from the basal wall.  $\times 490$ .
- Fig. 12. Hypha showing lateral origin of oogonia on long, straight stalks.  $\times 40$ .
- Fig. 13. A young oogonium and antheridium.  $\times 120$ .
- Fig. 14. One of the rare instances in which the antheridial branch has arisen from the hypha bearing the oogonium.  $\times 160$ .
- Fig. 15. An eccentric spore.  $\times 720$ .



*Saprolegnia terrestris* n. sp.



[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. II., 1937.]

ART. XVI.—*Basaltic Barriers and Other Surface Features of the Newer Basalts of Western Victoria.*

By Professor ERNEST W. SKEATS, D.Sc., A.R.C.S.,  
F.G.S., and ALBERT V. G. JAMES, B.A., M.Sc.

\* [Read 10th December, 1936; issued separately 19th July, 1937.]

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V. BYADUK.

- (a) Lava flows.
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- (c) Caves.
- (d) Steam blisters.

VI. AGE OF THE BASALTS.

## I. Introduction.

### (a) *Areas examined.*

The areas discussed in this paper consist of the Stony Rises of Porndon, the breached barriers of Dreeite, and the volcanic rocks of Byaduk. The area of the Stony Rises, wholly volcanic, has Mount Porndon near its western boundary, Lake Corangamite to the north, and Pirron Yallock near its eastern extremity. The centre of the area is about 14 miles west of Colac and 107 miles west of Melbourne.

The second and much smaller area near Byaduk, and lying about 16 miles south of Hamilton, which is about 200 miles west of Melbourne, is concerned with basalt flows from Mount Napier, partially filling valleys.

### (b) *Special interest of the surface in these areas.*

The special interest of these areas consists of the surface features of the basalts, the crowding of basaltic barriers (with intervening valleys), basins and knolls in the Stony Rises, and, in the Byaduk district, remarkable steam blisters, barriers and caves in lavas restricted to valleys. These features stand in marked contrast to the features of the basaltic plains commonly met with in Western Victoria, where monotonous plains of basalt extend over wide areas, diversified only occasionally with small isolated ridges or shallow depressions, apart from the numerous small, extinct scoria or lava cones or puyes.

### (c) *References to similar features.*

Ridges or barriers of basalt, often breached, and in some ways similar to those of Western Victoria, occur in other parts of the world. Geikie (1) has figured and described such features from the Snake River plains of Idaho. Stearns (2) has also described them, and they occur on a small scale among the recent lavas of Hawaii, where they are known as pressure domes or schollen-domes.

One of us (E.W.S.) paid a visit to Hawaii in 1934, and examined these breached pressure domes in the Kau desert, south of Kilauea. These features, developed on some of the recent lava flows, are much smaller and far less crowded together than the breached barriers of the Stony Rises, and are generally developed on a slope of much steeper gradient.

### (d) *Previous references to the Stony Rises.*

James Bonwick (3) in 1858, refers to the Stony Rises, and describes the basalt as "reared up as waves petrified in their rise. Huge barriers meet the eye on all sides, of heights from ten to sixty feet." He recalls that Darwin compared a similar scene he beheld to a sea petrified in a storm, but that no sea could present such irregular undulations, or could be traversed by such deep chasms.



J. W. Gregory (4) refers to the "lava streams, which have come from Mount Porndon . . . . an area of about 50 square miles, which is covered by ridges of piled lava blocks. These ridges are so rough and boulder strewn that they are known as the Stony Rises."

The authors (5) gave a very brief and preliminary description of the Stony Rises to the British Association (Centenary Meeting), 1931. More detailed work has led the authors to adopt a different view, presented in this paper, as to the methods of formation of the breached barriers. Apart from the above brief descriptions, the Stony Rises have not been scientifically described, and the Byaduk area, so far as we can find, has never been described.

(e) *Sub-surface geology.*

This paper is primarily concerned with the surface features of the basalts, and only brief reference need be made to the sub-surface geology.

In the Stony Rises, basalt covers nearly the whole area. Among the ejectamenta included in the scoria beds of Glen Alvie, near Red Rock, are fragments of plant bearing, freshwater, Jurassic felspathic sandstones, and of marine Cainozoic sediments. A small outcrop of fossiliferous Cainozoic (Barwonian) calcareous sandstone occurs just within the ring of Mt. Porndon at an elevation of about 650 feet, and similar rocks occasionally outcrop round the shores of Lake Corangamite at about the 400 foot contour line. The abundance of xenoliths, consisting of angular fragments of vein quartz, in the basalts of the Stony Rises, suggests the presence beneath the area of Ordovician sediments. Bedded tuffs somewhat older than the basalt flows are also met with round the shores of Lake Corangamite, and appear to be associated with a volcanic centre known as Vaughan's Island. At Byaduk the basalt from Mt. Napier flows in a valley where Cainozoic marine limestone is exposed on the lower slopes, and is overlain by basalt considerably decomposed.

(f) *Acknowledgements.*

The Air Force, through the courtesy of Wing Commander Cobby, took a series of air photographs of parts of the Stony Rises. A photo (Plate XIV.A), provided by Wing Commander Swinbourne, of a small area about  $1\frac{1}{2}$  miles south-east of Stonyford, near the Pirron Yallock Creek, shows the forms of the breached barriers and associated valleys. The maps and sketches reproduced in this paper have been re-drawn by Mr. J. S. Mann, of the Geological Department of the University of Melbourne. Mr. G. Harman, of Byaduk, has been very helpful in facilitating field work in the Byaduk district.

## II. The Stony Rises South and East of Lake Corangamite.

### (a) *Boundaries and area.*

The Stony Rises occur in two areas, one to the south-west, and the other to the east and south-east of Lake Corangamite (Fig. 1). The former area, covering about 80 square miles, is dominated by Mt. Porndon, and extends for 12 miles in an east-west direction from Pirron Yallock (101 miles west of Melbourne) to Weerite, and in a north-south direction for 8 miles from Lake Corangamite to Carpendeit. The southern shore of Lake Corangamite forms its northern boundary, while Pirron Yallock creek forms the southern and eastern boundaries. The eastern area around Dreeite covers about 100 square miles, and is dominated by the Warrion group of volcanoes. It extends for 15 miles in a north-south direction from Cundare to Robertson's Hill near Colac, and for 10 miles in an east-west direction from Beeac to the eastern shores of Lake Corangamite.

### (b) *Altitude.*

The contours of the Military Map of the area (Fig. 1) show that around Mount Porndon, 949 feet, the surface of the basalt sheets reaches an elevation of 600 to 650 feet, and slopes gently away from the mount in all directions down to the 400 feet contour around the shores of Lake Corangamite. It is clear that the lavas in this area came from the neighbourhood of Mount Porndon. On the south-east side of Lake Corangamite, similar levels of the basalt sheets are noticeable. The 600 to 650 feet contour line defines the base of the volcanic centre of the Warrion Hills, and from this area of eruption the surface slopes away in all directions. In a westerly and north-westerly direction, through Drecite to Lake Corangamite, the level falls from 650 feet to 400 feet. In this region it is clear that the basalt flows came from the direction of the Warrion Hills.

### (c) *Centres of eruption.*

The two main centres of eruption in this area are Mount Porndon and the Warrion Hills. The central cone of Mt. Porndon, which rises to 949 feet, consists of a central scoria cone with smaller scoria and lava cones, all later in origin than the main basalt sheets proceeding from this centre. Warrion Hill, 922 feet high, however, consists almost entirely of basalt. Other centres of eruption lie south from Warrion Hill and consist of the scoria cones of Alvie and Red Rock (Plate XII.A). The latter includes a number of collapsed craters of fine grained ejectamenta, while Lake Coragulac, just south of Red Rock, another centre of eruption, is a caldera of collapse. Robertson's Hill, 722 feet, about 6 miles south of Glen Alvie, consists of basalt. The two Nalangil Basins are also collapsed calderas. Vaughan's

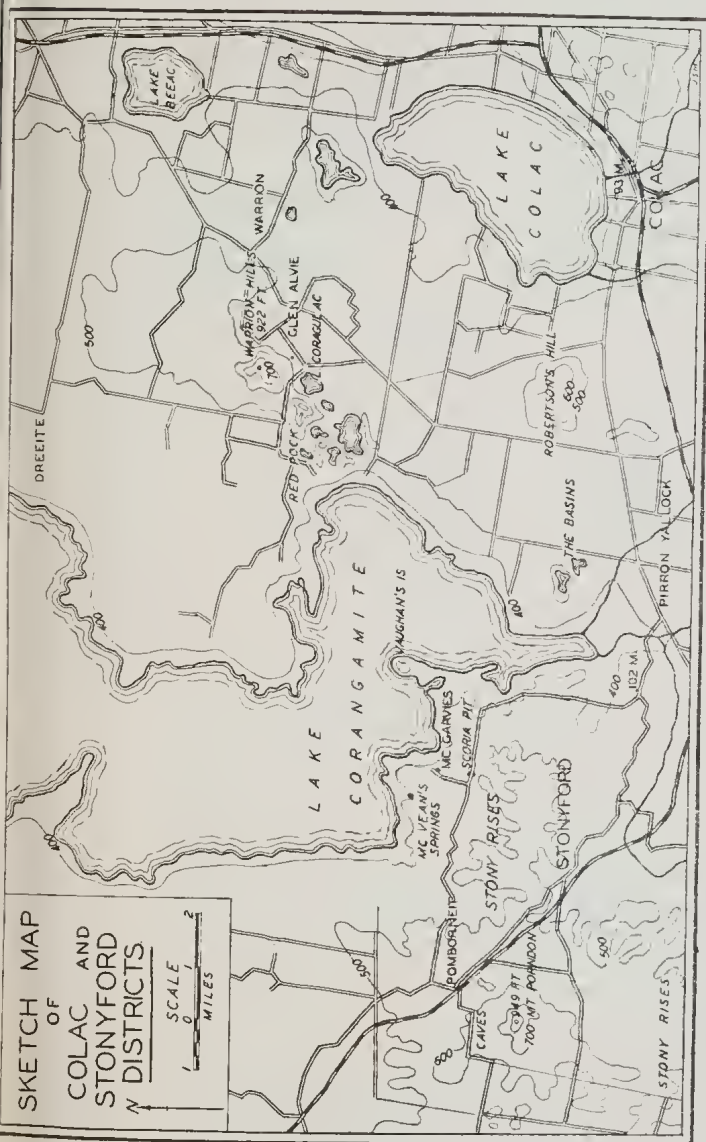


FIG. 1.—Sketch map of Colac and Stonyford District.

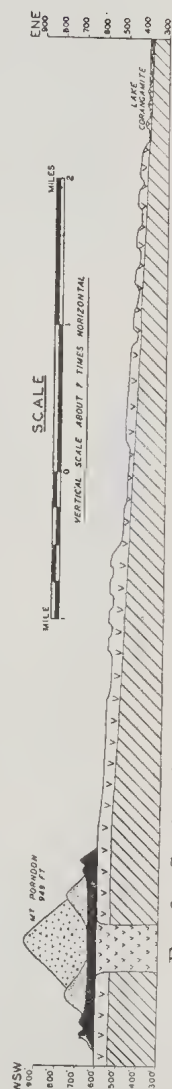


FIG. 2.—Section from Mount Porndon to Lake Corangamite, showing basaltic plateaux and lava tongues.

Island, projecting into the south end of Lake Corangamite, is another centre of eruption, and consists of coarse scoria passing outwards along the lake shore into fine grained tuffs, which appear to antedate the lava tongues projecting into the lake.

(d) *Composition and texture of the lavas.*

Since this paper is chiefly concerned with the surface features of the basalts, their petrography is important only in so far as it contributes to the development of these features. A brief statement of the textures and chemical composition of the basalts will suffice.

Two chemical analyses have been made by Mr. G. Ampt.

	I. 102 mile post W. of Pirron Yallock.			II. Later basalt from within Mt. Porndon ring.		
	Chem. Anal.	—	Norm. I.	Chem. Anal.	—	Norm. II.
SiO <sub>2</sub> ..	46·87	Quartz ..	..	51·36	Q ..	..
Al <sub>2</sub> O <sub>3</sub> ..	12·42	Orthoclase ..	7·40	13·05	Or ..	5·01
Fe <sub>2</sub> O <sub>3</sub> ..	2·34	Albite ..	21·13	2·36	Ab ..	24·80
FeO ..	10·54	Anorthite ..	14·68	8·89	An ..	19·99
TiO <sub>2</sub> ..	2·99	Nepheline ..	4·38	2·04	Ne ..	..
MnO ..	0·15	Diopside ..	21·95	0·12	Di ..	18·24
CaO ..	8·43	Hypersthene ..	..	8·56	Hly ..	20·97
MgO ..	10·31	Olivine ..	20·27	9·45	Ol ..	2·88
K <sub>2</sub> O ..	1·25	Magnetite ..	3·40	0·85	Mgt ..	3·42
Na <sub>2</sub> O ..	3·45	Ilmenite ..	5·67	2·93	Il ..	4·84
			98·88			
H <sub>2</sub> O ..	1·08	Water ..	1·08	0·38	H <sub>2</sub> O ..	100·15
			99·96			0·38
			Total ..			Total ..
			99·96			100·53
P <sub>2</sub> O <sub>5</sub> ..	tr.			tr.		
Total ..	99·83			Total ..		
			99·99			99·99
			Sp. gr. = 2·974			Sp. gr. = 3·063

The basalt from the barrier at 102 mile post is typical of all the basalt of the Stony Rises. It is a fairly coarse grained, somewhat cellular, holocrystalline, dark-grey andesine basalt, crowded with fairly large felspar phenocrysts. Under the microscope, R.S. 2844 [Numbers of rock sections apply to the collection in the Geology Department, University of Melbourne], the texture is coarse, and the abundant plagioclase phenocrysts, with symmetrical extinction angles of the lamellae, range from 14°-25°, indicating oligoclase to basic andesine. Some of the felspars have external growths or zones of later formed felspar of the composition of oligoclase (extinction angle 12°-15°). Olivine, in clear fresh crystals but with marginal alteration to iddingsite, is also plentiful. Numerous small, pale green augites are present, and long plates of black ilmenite are fairly conspicuous.

Rock section 2845 is a specimen from a tachylytic basalt selvage of a similar felspar basalt from a quarry near McGarvie's. It differs mineralogically from the previous rock in the absence of



augite, and in the fact that the bulk of the section consists of brown tachylytic glass. In this are set numerous phenocrysts of basic andesine (extinction angles  $25^{\circ}$ - $28^{\circ}$ ) and fresh, but in places, corroded olivine. It is clear that both plagioclase and olivine are intratelluric in origin, and that the composition of the glass is such that augite would have crystallized from the fluid part of the magma but for the sudden chilling at the surface.

Rock section 2846 is a specimen of a dense black olivine basalt from a younger lava of a ridge inside the Mt. Porndon ring and opposite to the Porndon Caves. Under the microscope the fine grained texture is noticeable, and additional evidence of rapid solidification is yielded by the presence of a considerable amount of brown glass in the matrix. The plagioclase is not nearly so abundant or conspicuous as in the basalt of the Rises, consisting of minute crystals with symmetrical extinctions up to  $30^{\circ}$ , i.e. acid labradorite. There is abundant quite fresh olivine, a fair number of small brown augite crystals, and numerous minute octahedra of magnetite.

Rock section 4896 is a specimen of a dense basalt flow over a scoria pit on the eastern side of Porndon (No. 2 analysis). The rock is a fine grained dense olivine basalt. Under the microscope the fine grained texture is noticeable. Fresh porphyritic olivines are abundant, and a few of the crystals have margins of iddingsite. The felspar is plentiful, consisting of small lath-shaped plagioclases with symmetrical extinction angles up to  $25^{\circ}$ - $27^{\circ}$ , indicating basic andesine. A fair quantity of brown augite, partly in brown phenocrysts, but mainly in small crystals and grains, is present, together with numerous minute cubes of magnetite. A fair amount of brown glass is present as groundmass.

Innumerable fragments of reef quartz occur as xenoliths in the basalt and in the scoria fragments throughout the Stony Rises. It is angular and fractured, and the pieces vary from a half inch to three inches in length (6).

Molten basalt has penetrated many of the cracks in the quartz fragments, and the rounding off of the solid angles indicates corrosion and a certain amount of assimilation by the liquid lava. It is probable that during the eruptions of Porndon and Warrior, quartz reefs in the underlying Older Palaeozoic rocks were reduced to fragments, and incorporated in the flood of lava that poured over this area. No waterworn quartz inclusions have been seen in the basalt, and therefore the Cainozoic gravels are excluded as a possible origin. It is, however, rather surprising that no fragments of sedimentary rocks have been found in the basaltic lavas of the district.

(c) *General surface features.*

It has already been indicated that for the western part of the Stony Rises the site of Mount Porndon is the source of supply of the lavas. The average surface slope of the basalts is very



low. From the 650 feet contour round Mt. Porndon in an ENE. direction to the 400 feet contour at Lake Corangamite near McGarvie's, the distance is about 5 miles, and the average slope is only about 1 in 105, or 48.5 feet per mile. From the same centre in an ESE. direction towards Pirron Yallock, the distance to the 400 feet contour is about 7 miles, and the average slope is therefore about 1 in 150, or 34 feet per mile. It should be noted, however, that two plateaux with short, steeper slopes connecting them, occur within these limits, so that for considerable distances the average slope of the basalt surface is much less than the figures quoted above. Between the 650 feet contour at the base of the Warrion and the 400 feet contour at Lake Corangamite near Dreeite, a similar drop in level of the basalt surface occurs in about 4 miles, an average slope of 1 in 84 or 61 feet per mile.

The surface of the basalt in the Stony Rises is characterized by open polygonal joints, so that all the rainfall over the area readily sinks through the basalt to the underlying Cainozoic sediments. In consequence of this there is not a single flowing surface stream in the whole area, but hundreds of windmills provide the dairy farmers with water from the underground storages. The Pirron Yallock Creek defines the southern and eastern limits of the Rises, and flows into Lake Corangamite. The underground drainage from the Stony Rises enters by springs and seepages into the Pirron Yallock Creek and into Lake Corangamite. The most important of these are McVean's, Oliver's, and Carey's. Five million gallons of fresh water emerging from beneath the basalt daily enter Lake Corangamite from McVean's springs.

Between the striking and crowded basaltic barriers occur depressions of various shapes and sizes, sometimes funnel shaped, more generally elongated, and often with smaller eminences as hummocks or knolls rising from them. While no flowing surface water traverses these depressions, the bottoms of many of them, owing to the accumulation of basaltic soil, have become alluviated. This alluvium has a flat surface, and often partially covers the hummocks or knolls. In consequence, such areas are retentive of surface water, and in wet weather become small lakes or swamps.

These depressions below the basaltic barriers are often elongated and sinuous, and superficially simulate erosion features. Their longitudinal gradient, however, is undulating, not regular, and many of these depressions are closed basins not infrequently funnel shaped (Plate XII.B). They are, therefore, clearly not erosion features, but part of the solidified surface of the original basaltic sheets, and their present positions and attitude are to be attributed to subsequent sagging and fracture of the basalt crust, and not to erosion.

The barriers, valleys and funnel shaped depressions all constitute part of the original crust of the basalt sheets which have developed their present aspects by subsequent undulations of the crust. This is clearly indicated by the fact that the original polygonal jointing of the basalt crust developed in cooling is everywhere evident on the surface, the joints always being at right angles to the cooling surface, so that they are vertical on the crests of the barriers and at the bottom of the valleys or depressions, and are inclined towards the barriers in the slopes between barriers and valleys (Plate XIII.A). Very little scoriaeous or ropy basalt occurs in the Stony Rises; it is nearly all columnar, but in a few places a tachylytic selvage to the basalt is present. All of the flows are of the Pahoehoe type of basalt.

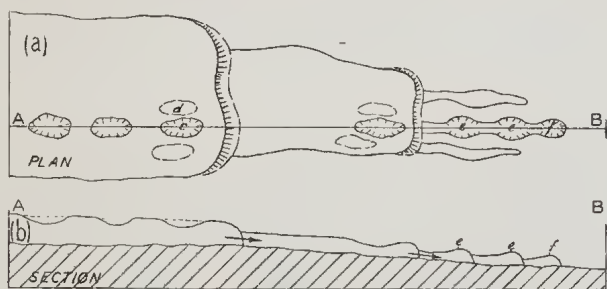
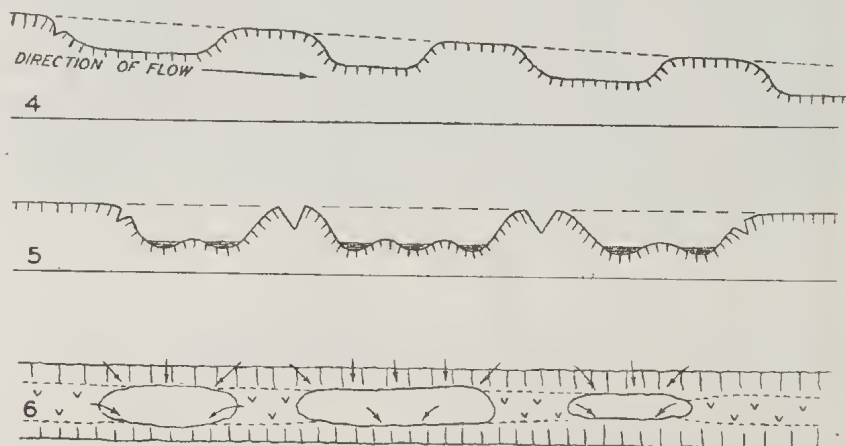


FIG. 3.—Plan and section of basalt plateaux and lava tongues.

Thousands of barriers occur in the Stony Rises, and every one examined by us is more or less breached. Sometimes this process is only slightly evident. The top of the basalt dome or barrier is either slightly flattened or has sagged a foot or more between prominent open columnar joints. In very many spectacular cases of breaching, a very definite minute "graben" or sharp depression represents a collapse of the top of the barriers which in some cases amounts to over 20 feet in depth. At the base of the trough there is generally an accumulation of deep red basaltic soil. In a few cases near McGarvie's, on the shores of Lake Corangamite, hardened tuff is present in the trough. At the 102 mile post from Melbourne on the main road, a basaltic barrier is exposed in section in the road cutting. This barrier of solid basalt is about 30 feet in height, and has collapsed only slightly between two major joints or cracks which are about 2 to 3 feet wide above, and gradually close below. The space between the joints is filled partly with basalt fragments, and partly with bright red, fine grained tuff. In places this baked tuff is in contact with the gaping joint surface of the basalt which here has a selvage of tachylyte about 1 inch in thickness.

At the eastern end of this barrier the sloping surface of the basalt has a definite tachylytic selvage, and red, fine grained baked tuff is in contact with it, and a definite prismatic structure

in the tuff is developed for about 3 inches from the tachylytic basalt (Plate XIII.B). The inference is here drawn that a shower of tuff must have fallen on the basalt surface, so soon after its extrusion that while gaping joints had already developed, the surface of the basalt must have been still so hot as to have baked and prismaticised the tuff.



FIGS. 4.—Original slope of basalt plateau, Dreeite. 5.—Plateau and barriers at same height, Stony Rises. 6.—Suggested origin of barriers and depressions, Stony Rises.

(f) *The Stony Rises around Mount Porndon.*

East and south-east of Mount Porndon, outside the Ring, and starting from above the 600 feet contour line, a broad plateau extends for about a mile and a half (Fig. 2). This plateau is diversified with one very large breached barrier about 40 feet in height, and about 600 yards long on the north-east side of Mt. Porndon, and having an extension in a north-easterly direction. Apart from this prominent feature, only small domes and flat ridges rise above the plateau, and shallow depressions sink beneath the plateau level. Near the outer edge of the plateau large breached barriers, closely spaced and irregular in shape and direction, are a prominent feature. East of this rugged area the basaltic level falls rather abruptly about 30 to 40 feet, and further east another lower basalt plateau continues. In this case the plateau level is defined by the tops of the numerous breached barriers spread closely and irregularly over the area (Fig. 5). The plateau descends to about 450 feet near Lake Corangamite, and below this, fingers of basalt descend to lake level and enter the lake (Plate XII.c). The road about a mile west of Pirron Yallock also descends this plateau edge, and the easterly limit of the basalt ridges descends here nearly to the 400 feet contour. In the areas where the breached barriers are most closely crowded, they attain their maximum height, one of those measured reaching

a height of 65 feet above the adjoining depression. Probably the average outer slope of such barriers is about  $25^{\circ}$ , but in some cases it is very much steeper, up to about  $50^{\circ}$ - $60^{\circ}$ , and occasionally the walls of a few barriers may have an outer slope of  $70^{\circ}$ - $80^{\circ}$ . In all cases, whatever the slope or size of the barrier, it is always more or less breached, and the basalt is always columnar with the long axes of the columns at right angles to the basalt surface. A variety of hypotheses have from time to time been put forward to try to explain the formation of these barriers or apparently similar features. Lateral pressure on the solid crust of a lava sheet has been invoked. Some small features seen within the Halemaumau crater on Hawaii, and very small anticlinal arches in the basalt on the shores of Lake Corangamite (Plate XIII.c) appear to have this mode of origin. But a lateral thrust on a crust due to pressure of molten basalt from a higher level would develop asymmetrical slopes and varying heights, while the slopes of these barriers are normally symmetrical, and the crests of the barriers are at a fairly uniform height. Irregularities, amounting to submerged ridges in the topographic surface beneath the molten basalt, leading to an upthrust of molten basalt against the buried ridge and causing a bending up of a solid but somewhat plastic crust, have also been suggested as likely to develop breached barriers. This seems a quite feasible explanation for isolated or occasional and widely spaced domes or barriers rising from a basalt plain, especially where such barriers rise to varying heights. Some such isolated features seen on the Newer Basalt sheet at South Morang, north of Melbourne, may owe their origin to such a cause. But the presence of closely spaced breached barriers in hundreds within a few square miles would seem to necessitate the appeal to a buried surface of such extraordinary irregularity as to exclude it as a possible reason for the development of the barriers, apart from other objections.

The authors, in an earlier brief preliminary statement, suggested that the barriers may have marked the position of very numerous small fissures up which a limited amount of basalt was injected, but such a view is now seen to be untenable. The hypothesis now favoured and put forward with some confidence is one of partial collapse of the solid crust of a basaltic sheet due to the withdrawal of molten basalt from beneath, as a result of ruptures of the temporarily solidified front of the basalt sheet. Such ruptures occurring in a number of places would allow of large withdrawals of molten basalt from beneath the crust of the plateau, and lead to subsidences of the crust where withdrawal of lava occurred. Undulations are started, the surface area of the crust is increased, tensional stresses are set up, and fractures along the polygonal joints occur, especially at those parts of the crust of the plateau which do not sink, and therefore form the crests of the domes or barriers. In this way the



breaching of the barriers accounts for much of the increased length of the cross section of the basalt crust, and general small openings of the universal polygonal joints account for the remainder (Figs. 5 and 6).

Reference is made above to the picture of a temporary stoppage of the front of the basalt sheet as a result of surface solidification, causing the front of the sheet to stand as a rampart with a fairly steep slope. The continued outflow and downflow of molten lava from the vent or source at a higher level, however, causes pressure, leading to rupture in many places at or near the base of the solidified front. Molten basalt pours outwards and downwards from such ruptures, the streams become confluent and a second and slightly younger sheet or plateau of basalt is formed at a lower level (Fig. 3).

The topography of the Stony Rises, as mentioned above, shows the existence of two such plateaux at levels between the 600 and 400 feet contours, and close examination at the junction of the higher with the lower basalt plateau surface, especially north of the road about a mile west of Pirron Yallock, confirms the view that such ruptures of a basalt front have occurred, and later flows have developed a plateau at a lower elevation.

While this paper was being written, a paper by Robert L. Nichols (7) came to hand, in which basalt flows in New Mexico are described. The consolidation of the front of a flow, the rupture where the crust is weak, and onflow of the molten basalt at a lower level, are described and figured. It is clear from this account that somewhat similar conditions attended the flowing of basalts in New Mexico as those which are met with in the Stony Rises. In this paper two depressions on the surface of the flow similar to those in the Stony Rises are figured in diagram but not discussed.

The reasons for the development in the Stony Rises of plateaux at different levels, the abundance and crowding of barriers and valleys, and their large dimensions, are no doubt complex, and the conditions must be different from those obtaining in other parts of Victoria where basaltic lavas are poured out in a succession of comparatively thin sheets with a comparatively level surface.

The very gentle slope of the pre-basaltic land surface in the Stony Rises favours slow movement of the lava, but normal basaltic lava is very fluid and would move rapidly in thin sheets. But all of the basalt of the Rises is crowded with porphyritic feldspars of intratelluric origin, and this must impart a certain amount of viscosity to the flows. Again, the field evidence suggests that the basalt poured out from the source in a single flow about 80 feet in thickness. The peculiarities of the basalt surface which are such a striking feature of the Rises appear to have developed as a result of the combination of several causes,



including the eruption of a thick sheet of lava over a gently sloping surface, and the rapid formation of a solid crust and front assisted by the abundance of felspar crystals. The great thickness of the lava sheet, however, enabled it to maintain internal fluidity, and this led to numerous ruptures at the base of the snout of the main flow and the extrusion of a series of subsidiary flows at a lower level. These later flows united to form a lower plateau, and the draining away of the liquid lava from under the solid crust in the higher plateau led to the development in it of numerous depressions and sinks, and to the crowding between them of breached barriers.

Valleys, etc.—The picture, developed above, of the formation of a lower basalt plateau in front of a higher plateau by rupture in many places of the solidified front of the flow, involves the withdrawal of large quantities of molten lava from beneath the crust of the upper plateau. Where the withdrawal is over a wide area, a general sagging of the solidified basalt surface may occur, leading to the formation, within the basalt plateau, of a broad area of subsidence which, if the subsidence and sub-surface are uniform, develops into a flat basin with marginal rims whose sides are opened by tension cracks (Figs. 5 and 6). Sometimes the broad collapsed area will have occasional undulations, and the fixation of the positions of the relatively elevated parts may be brought about in at least two ways. In the one case the basalt crust may vary in thickness, and the position of the ridge above the general level of the basin may be determined by the thickest part of the basalt crust. On the other hand, irregularities in the sub-basaltic topography are likely to be present. If so, the position of a sub-basaltic ridge is likely to locate the positions of a basaltic ridge on the surface of the depressed area, for away from such ridge there will be a greater thickness of molten basalt which is likely to be drained away, causing the basalt crust over such an area to sink to a lower level than over a buried ridge.

Where the breached barriers are most closely spaced and irregular in shape the intervening valleys are correspondingly restricted in width and irregular in plan. The removal of most of the molten basalt from under a wide area will tend to develop crumpling of the solidified basalt crust with the consequent formation of irregular valleys as well as breached barriers. Not only are these valleys often irregularly shaped or winding in plan, but also in thalweg or longitudinal profile. This at once distinguishes such valleys from those produced by erosion (Plate XIV.A). Inequalities in the amount of subsidence of the crust from point to point are the cause of such a profile.

A remarkable type of valley which is fairly common in the Rises is one which is irregularly ring-shaped, with a central knoll or ridge often connected to the side of the valley by a low connecting ridge. It is difficult to picture the precise mechanism of formation of such a feature.

In several parts of the basalt plateau the depressions are elliptical in plan and arranged in a linear direction. Sometimes they are circular in outline and constitute inverted cones. The shapes and linear direction of such features almost certainly mark at the surface, the positions beneath the basalt crust of "lava tunnels," or narrow valleys along which molten basalt has been drained away (Fig. 7). Such funnel shaped depressions carry down rain water easily; in places there are open joints, enabling one to see that beneath the apex of the cone caverns occur. The Pomborneit butter factory used to get rid of all its effluent by piping it to one of these conical depressions.

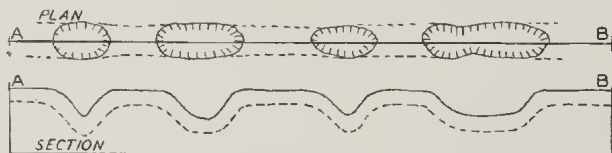


FIG. 7.—Plan and section of elliptical depressions over collapsed lava tunnels.

Gas Explosion Crater.—Near the caves of Mount Porndon a remarkably symmetrical surface feature occurs. It is a ring, about 50 yards in diameter, of basalt and basalt blocks raised about 10 feet above the level of the basalt outside. Within the ring the columnar basalt has its joints radially disposed. The central level depression of reddish soil is just below the level of the basalt outside the ring (Plate XV.A). It seems probable that the formation of this feature is due to the development of a large gas blister beneath the solid crust, causing it to be domed up, and later, when the joints developing downwards weakened the crust of the dome sufficiently, a small gas explosion occurred sufficient to form the slight rim or ridge around the central depression (Fig. 8).

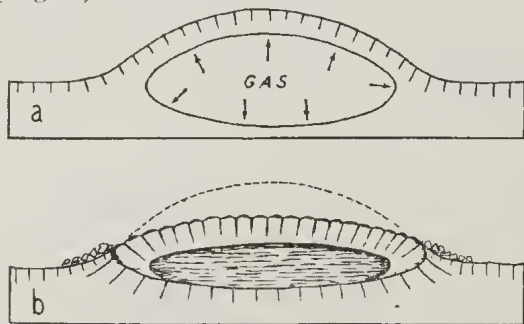


FIG. 8.—Gas explosion crater near Porndon Caves—(a) early development, (b) present appearance.

Caves.—Just outside the Porndon ring are two basalt caves. Each of these is situated beneath a broad, low dome of basalt.

The more southerly cave (Plate XVII.A) has a collapsed area in front with a natural arch formed of the basalt crust between the collapsed area and the mouth of the cave which is a natural arch (Figs. 11 and 12). The arch is interpreted as a swelling due to gas pressure between the molten basalt and the solidified crust, forming a cupola on the walls of which are small, pendent lava stalactites about  $1\frac{1}{2}$  to 3 inches long. This cave, trending due

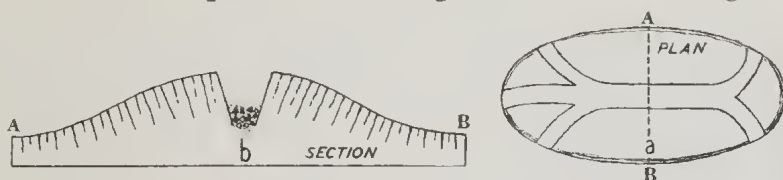


FIG. 9.—Plan and section of breached barrier, Dreeceite.

north, has a flat floor, and against the walls at the base is a basaltic ridge about 2 feet high constituting the frozen edge of the lava which has since withdrawn along the lava tunnel.

The second cave is about 300 yards north-west from the one just described. This cave has no arch at the entrance, but collapse of the roof has yielded a fairly flat hole. The cave formerly could be penetrated for over 200 yards, but collapse of part of the roof basalt about six years ago has now restricted the

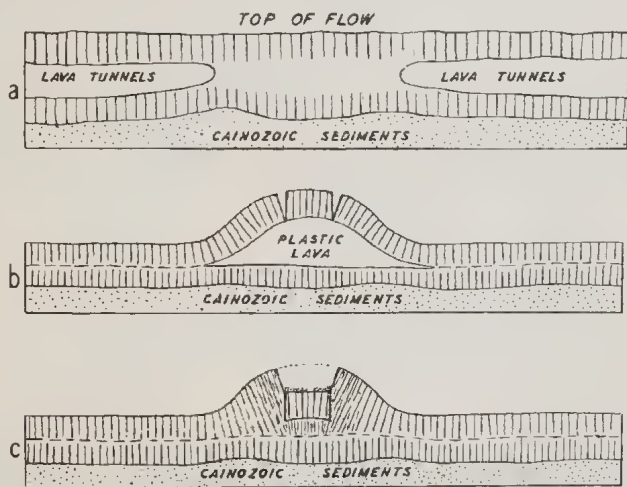


FIG. 10.—Probable origin of deeply breached barrier, Dreeceite—(a) Flow with lava tunnels; (b) Subsidence of lava above tunnels; (c) Collapse of arch of barrier.

underground passage to about 50 yards in length. From the roof of this cave, small, pendent lava stalactites are to be seen. The floor is arched, with a central breach. Not only are there marginal frozen edges to this cave, but the walls of the lava tunnel are

smearred with residual ropy basalt left by the retreating molten lava. Along the length of the roof of the cave two dome-shaped gas cupolas are developed, whose apices rise about 40 feet above the floor of the cave, and 20 to 30 feet above the roof of the lava tunnel, which is about 30 feet in width.

(g) *Dreeite*.

The chief topographical features of the Dreeite area are, (1) the gradual slope of the basalt surface from the Warrion Hills down towards the shores of Lake Corangamite, (2) the relatively broad, depressed areas of basalt surface, and (3) the rather widely spaced, but very conspicuous, breached barriers. The origin of these features is similar to that already described for the Stony Rises around Porndon. The chief interest centres in the breached barriers, many of which are of large dimensions. The central breach or minute "graben" may have a depth exceeding 20 feet (Plates XIV.c, XV.B, Figs. 9 and 10).

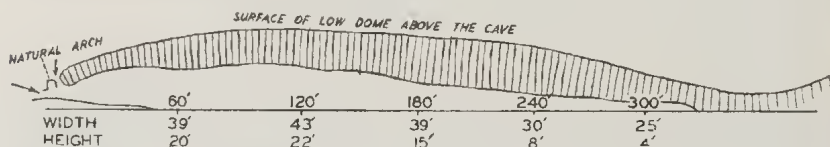


FIG. 11.—Longitudinal section of S.-E. cave near Mount Porndon.

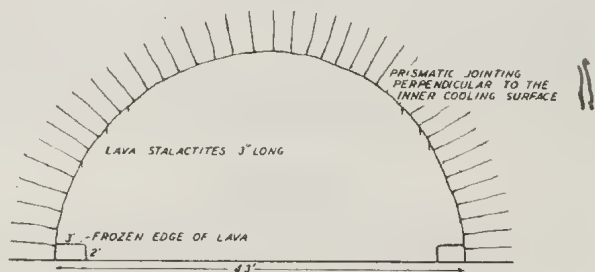


FIG. 12.—Transverse section of S.-E. cave near Mount Porndon, with lava stalactites and frozen edge of lava.

A view from one of the larger barriers towards Lake Corangamite shows by theodolite measurement that the summits of intervening barriers maintain a constant downward slope towards the lake (Fig. 4), probably indicating the original level and slope of the top of the lava crust before subsequent subsidence of the surrounding depressed areas.

At the base of the breach in each barrier there has accumulated red basaltic soil to a thickness which in some cases reaches 3 feet. From the western boundary of the basalt plateau, tongues or fingers of basalt, themselves usually breached, have flowed towards and into Lake Corangamite.



### III. The Southern and Eastern Shores of Lake Corangamite.

#### (a) *The Ridges.*

The main sources of supply for the basalt reaching Lake Corangamite came from Mount Porndon, moving in a north-north-easterly direction, from Robertson's Hill, moving in a north-westerly direction, and from the Warrion Hill, moving in west and north-west directions. From the edge of the main flows at about the 450 feet contour, molten lava breaking from the base of the flows poured lakewards in a series of small, linear, finger-like protrusions down to the lake shore, and project in some places for several hundred yards into the lake. The general direction of these small flows is radial to the shore line and their longitudinal profile is undulating. Temporary solidification of the snout of the flow occurred, the pressure of molten lava from behind developed a bull nosed knoll or ridge, and rupture at the base led to the continuation of the flow at a lower level. This is sometimes repeated several times before final solidification terminated the movement. The surface of these small flows is, in places, marked by tranverse ridges and joints, and in places it is clear that opening of these joints occurred while liquid lava, under some pressure, was moving beneath, for in several cases a small amount of ropy and scoriaceous lava has been squeezed out through the original joints (Plate XVI.A). Many of these small ridges show small true breaches at their summits, but in addition, a number of ridges occur on the lake shore and up to an elevation of 15 feet above it, constituting pseudo-breached barriers (Plate XV.c and Fig. 13). There is clear evidence that at one time the lake level was from 5 to 15 feet higher than at

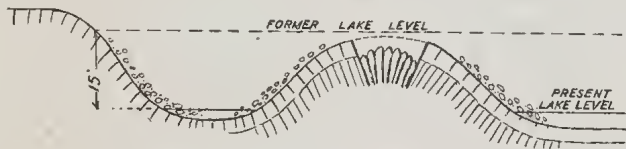


FIG. 13.—“Pseudo breached barrier” and basalt shingle on slopes, with former lake level, shores of Lake Corangamite.

present, and wave erosion has removed the rather vesicular upper crust of the crests of these ridges, exposing basalt with a distinct joint system beneath. In addition, the eroded material has accumulated on the slopes of these barriers as a waterworn basaltic rubble. This is abundant up to 5 feet above the present lake level, and in some places has been noticed up to 15 feet above the present lake surface. It has been flung into breaches of the barriers and along pockets of the shore line. A noticeable feature of nearly all the small lava tongues on the shores of Lake Corangamite is that the original tachylytic selvage, up to  $1\frac{1}{2}$  inches thick, common to Pahoehoe flows, has been preserved.



*(b) Lake Corangamite, Dimensions and Salinity.*

The lake has a maximum length of 20 miles, a maximum width of 7 miles, a minimum width of  $1\frac{1}{2}$  miles, its area is 81 square miles, and it has a perimeter of 81 miles. It is remarkably shallow; one of us (A.J.) has made hundreds of soundings, and nowhere has it a depth greater than 5 feet, though, in the south-west, there is a thick deposit of soft silt over the floor of the lake. This can be penetrated by a stick to a depth of 9 feet. Although the lake in recent years has varied little in depth, there is evidence to show that there have been considerable variations during its past history. Local residents remember a time when cattle, to reach Vaughan's Island, had to be taken there by punt, although it is now a tied-island connected to the mainland by a neck of land 5 feet above the present water level. To the south-east of the lake, there is a plain of tuff and alluvium nearly 2 miles wide, and so level that there is little doubt that it was at one time part of the lake bed. The name given by the aborigines to this area is Pirron Yallock, which means "shallow water."

Lake Corangamite, containing 10.5 lb. of salt per 100 lb. of water, is three times more saline than the sea. This great salinity is due, not only to the fact that the lake is a basin of internal drainage, but also to its shrinkage in volume. Shrinkage has occurred in all the lakes examined throughout the district.

*(c) Tuffs and their Relation to the Lava Barriers.*

Extending along the southern margin of the lake are tuffs, mostly very fine grained. They extend from below water level to about 5 feet above the present surface of the lake. Nowhere are tuffs found in this area at higher levels, and as they are widespread along the lake shore within the limits given above, it is reasonably safe to conclude that these tuffs were laid down in the lake when it was 5 feet or so higher than at present. The presence of numerous shells of *Coxiella* embedded in the tuff 1 mile north-north-west of J. McGarvie's strengthens the belief that the tuffs are of lacustrine origin. The tuffs extend far out into the lake on all sides of Vaughan's Island.

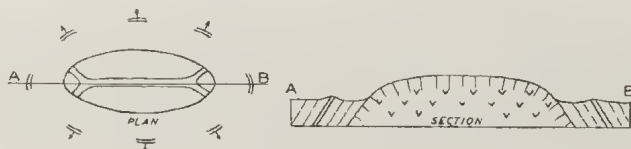


FIG. 14.—Plan and section of barrier with tuffs dipping away from it, near McGarvie's.

In the Red Rock, Warrion, and Porndon areas, there are thick beds of tuffs which are unquestionably younger than the felspathic lava ridges, for their undisturbed strata cover the broken surfaces

of the ridges. Along the southern shores of Corangamite, however, the lava ridges are younger than the tuffs, for in several places near McVean's Springs the lava ridges rest on the tuffs, while near McGarvie's there are two localities where small shoots of tachylytic lava are seen invading the tuffs (Fig. 15c). In most cases the tuffs are found completely or partially surrounding the lava ridges and knolls (Fig. 14), but inclined away from them, as though the barriers had been gently raised through the horizontal tuffs and had uplifted them bodily on their flanks. The inclination of the beds in these instances is the opposite to what it is where the lava barrier is resting on the tuffs (Fig. 15). In the latter case the tuffs are inclined towards the lava as though the weight of the lava mass was bending down the beds. In several places the tuff near the front of the ridge was seen to be puckered and to be neither inclined towards nor away from the lava. Generally there is, at the surface, a gap of one or two feet between the lava and the tuff outcrop. This is probably due to drainage upwards of the underground water from the Rises, altering the tuff to a black clay. All stages in this alteration have been observed by making a shallow trench between the basalt and the exposure of dipping tuff.

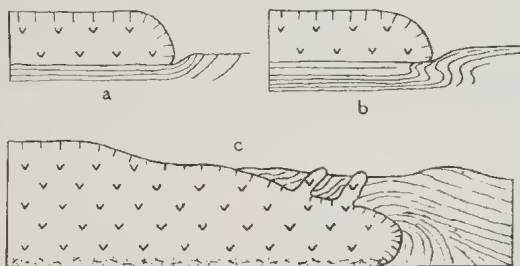


FIG. 15.—Section of basalt flow pressing down tuffs, Lake Corangamite; (a) with inward dip; (b) with crumpling; (c) with intrusion of basalt "squeeze up" into contorted tuffs.

It is likely that the tuffs were derived from the Vaughan's Island volcano, and that they formed thick unconsolidated strata in the coastal waters of Southern Corangamite. While they were in this state, the lava tongues from Porndon and Warrion poured into the lake. Some lava tongues flowed over the tuff and compressed it, but most of them appear to have flowed against the soft beds and pushed them ahead, or ploughed through and under them. In the last case, beds of tuff were left resting on the sides of the barriers and inclined away from them. Some low knolls are completely surrounded by tuff beds. They are parts of a lava tongue, the lower portions of which lie beneath the tuff. The tuff found within the breaches of some barriers is probably redistributed material as it is not stratified.

#### **IV. Mount Porndon.**

##### *(a) General Outline.*

The centre of eruption within the Mount Porndon ring has probably played a more important part in the geological history of the district than have higher neighbouring volcanoes such as Leura and Noorat. Mount Porndon is surrounded by a remarkable lava ring barrier about 2 miles in diameter (Plate XIV.B). Within this ring are lava plains, deep depressions, and groups of low scoria cones and lava domes. Outward from the ring there is a general fall of level in all directions, therefore this centre of eruption is to be looked upon as the source of most of the lava south of Corangamite.

##### *(b) The Ring Barrier.*

This remarkable basaltic ridge (Fig. 16), standing generally 50 to 80 feet above the plains and ridges outside, extends in an almost unbroken line around Mount Porndon. It is 8 miles in length, is roughly circular in shape, and on all sides presents a steep outer slope with an angle of rest about  $30^{\circ}$ – $40^{\circ}$  (Plate XVI.c). That this outer face of the barrier is the original cooling surface is shown by the presence of lava columns perpendicular to its surface. Many columnar blocks have been displaced, but sufficient remain in situ to show that the lava solidified in that position. The external height of the Ring varies from place to place. One feature on which this height depends is the nature of the surface on which it rests. Where the Ring Barrier rests on a ridge, the Ring appears low, but where it is above a depression it is high. The Ring reaches its greatest height (84 feet) above the plains near the Stonyford-Cobden road. The internal height of the Ring, which varies from place to place, is considerably less than the external. Around the outside base of the Ring Barrier there is generally a depression some yards in width and a few feet deep, apparently made by the compression of the underlying lava while in a semi-solid state, by the mass of rock above it.

The inner face of the Ring Barrier is invariably fractured along one, two, three or four curved lines, two being the most common, and more or less concentric with the outer margin of the Ring. In some cases there has been considerable collapse along these fracture lines, extensive areas subsiding 30 feet or more (Plate XVI.B). Whereas the outer slope of the Ring exposes the transverse polygonal tops of the basalt columns, longitudinal sections are shown on the fractured inner face. The effects of gravitational collapse along tension cracks are everywhere apparent along the inner slope of the Ring. Cracks several feet wide and 20 feet or more in depth are common. Underground gaping joints are numerous.

The ring barrier is composed of the same coarse felspathic basalt as is met with in the Rises. Little scoriaceous or ropy lava is present, though there is one locality where small scoriaceous fragments extend from the top to the bottom of the outer slope, a distance of 60 feet. Dr. A. Wade (8) has referred briefly to extinct volcanoes in Madagascar, and in a personal communication states that great walls surrounding some of the extinct cones in Madagascar appear to be similar in nature to the Porndon Ring.

*(c) The Lava Sheet and Depressions within the Ring.*

The basalt surface inside the Ring Barrier has similar features to the lava sheet outside the Ring, i.e., it is not flat but hummocky, and is composed of the same kind of lava as the Ring and the plains outside. From the fractured face, the sheet slopes inwards until it meets the more recent accumulations of lava and scoria within the Ring. In the south-west, and more particularly in the north-east, there occur depressions, circular or elliptical in outline, and 40 to 50 feet in depth. The largest, 100 yards in diameter, occurs fairly close to the Ring south-east of Porndon. Three of these large inverted cones are within two or three hundred yards of one another (Fig. 16). All have columnar jointing perpendicular to the surface, and all have severely fractured rims, the fractures being about 10 feet in depth. Contrasted with these is the depression D.D. on the map, which is formed by the confluence of the edge of a lava flow and the sloping flanks of two scoria cones. It is therefore not formed by subsidence.

*(d) Lava Hills within the Ring Barrier.*

Around the foot of Mount Porndon and the small scoria cones are several low basalt hills from which short lava streams have issued, in two instances reaching the Ring Barrier and overwhelming it. This basalt is quite distinct from the coarse highly felspathic and lighter coloured basalt of the Ring. It is very fine grained, rich in olivine, and dark in colour. As it overlies the felspathic basalt of the Ring and the plain inside it, it is obviously younger than these. The chemical composition, texture, and mineral composition of this basalt have been described above.

*(e) The Scoria Cones.*

The four highest hills within the Ring Barrier are all scoria cones, only one of which, to the west of Mount Porndon, 949 feet, has a crater. The fragmental material of which they are composed ranges from isolated basaltic blocks on the sides of the cones to the finest ash. Several pits have been opened up to obtain scoria for railways and roads. In these pits olivine bombs, which range in length from 2 inches to 2 feet, are plentiful.



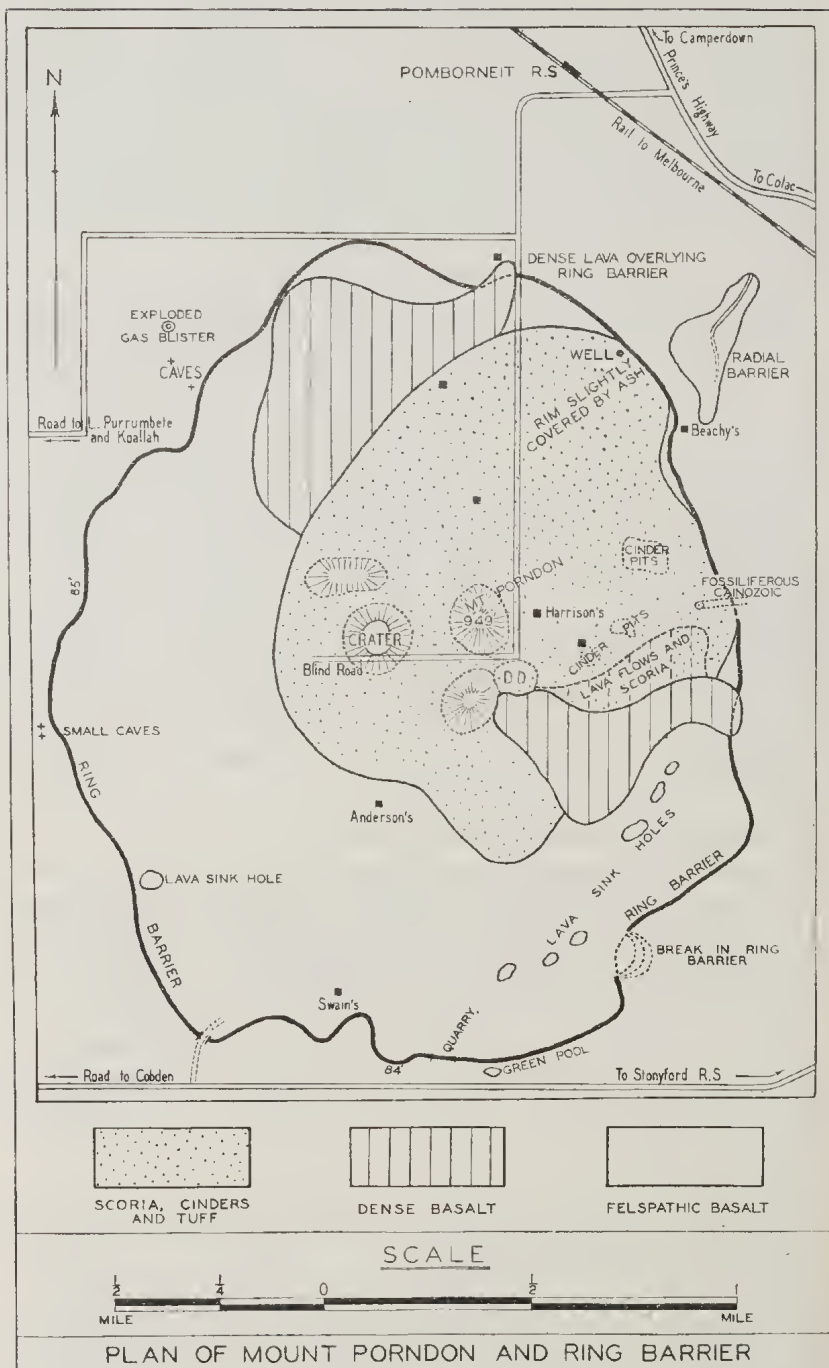


FIG. 16.



Fragments of both the earlier felspathic lava and the later dense type are found among the ejectamenta in the pits and on the sides of the cones, thus showing that the explosive phase of Porndon was its last. The north-eastern portion of the Ring is partially hidden beneath the ashes from Porndon. Here the outline of the Ring can be seen, but its contour is smooth and flattened out. A temporary railway line was made many years ago into the cinder deposits on the eastern slopes, and excavations revealed a marine Cainozoic deposit beneath the ashes and lapilli at an altitude of about 650 feet. It is reported by local residents that they obtained many shells from it. Though the authors found there marine Cainozoic polyzoa, and shell fragments, no whole shells were found. The exposure has been buried beneath discarded materials from neighbouring pits, and consequently it is difficult to reach and examine the Cainozoic calcareous deposits. Some beds of lapilli have been so cemented by calcareous deposition around each grain that the beds have been consolidated and greatly hardened. Considerable quantities of Cainozoic gritstone and ironstone are found about the slopes of the scoria cones, thus showing that the underlying rock consists of Cainozoic sediments.

(f) *Radial Barrier outside the Porndon Ring.*

Midway between the Pomboineit railway station and Mount Porndon is a conspicuous barrier outside but close to the Ring, and radial to it. It stands well above the hummocky plains around it. In plan it is roughly triangular, with the narrow base separated from the Ring by a valley-like depression. It is about 600 yards long. A deep trench extends along the crest of the ridge, and fractures also occur along its south-eastern margin. Basaltic ridges and depressions, higher than the low hummocky plains but lower than the radial barrier, occur along its sides. The general slope of these is away from the high triangular ridge. The whole area, plains and barrier, is composed of the same type of rock as the Ring Barrier, i.e., coarse felspathic basalt.

(g) *Geological History of the Porndon Series.*

Before the high scoria cones existed, the Porndon area was a centre of eruption from which thick sheets of felspathic lava covered about 80 square miles of the surrounding district. Belonging to the first eruption was the radial barrier referred to in (f) above. It was possibly on an earlier water parting, for the lava surfaces on all sides slope away from it. As the movement of the lava within the sheet continued towards the lower levels around Corangamite, so the crust of the basalt about the radial barrier sank to its present level, but the basalt now constituting the barrier being, on this hypothesis, on a divide, did not sink. Owing to the subsidence along its sides, deep trenches were

formed along its crest. Other hummocky areas were formed by differential subsidence in many parts of the district. The next phase was the formation of a sheet of lava up to 84 feet in thickness, which issued from a vent or vents within the present Porndon Ring. This thick sheet, flowing on irregular ground with little outward slope in any direction, moved forward only slowly. The front of the sheet solidified, and owing to the pressure of the lava from the source, it became exceptionally steep and high. At this stage the lava pancake is pictured with a slightly domed surface and a steep convex front (Fig. 17A). Withdrawal of molten lava from beneath the crust of the thick sheet is then pictured as having taken place. In a few cases this withdrawal appears to have been caused by the liquid lava breaking through the front of the pancake (Fig. 16), but it is probable that most was withdrawn through the vent or vents up which it rose (Fig. 17B). Several features resulted from the

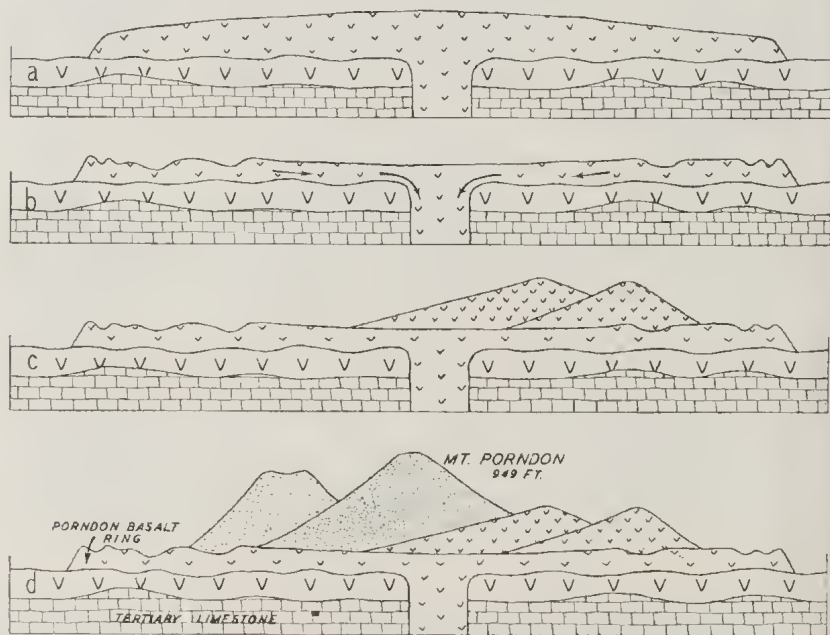


FIG. 17.—Four stages in the development of Mount Porndon, other cones, and Porndon Ring Barrier.

removal of lava from beneath the surface crust. In the first place, a somewhat irregular surface was formed which everywhere sloped inward from the edge of the pancake; secondly, deep depressions resembling huge sink holes were made by the local removal of support from beneath the crust; thirdly, fractures developed concentric with the solidified outside edge. The state of tension set up resulted in the separation of the

columns from one another, and deep crevices were formed. Lastly, a roughly circular ridge was left along the front of the thick sheet. The pressure of this sheet of lava on the partly solidified earlier flow, is probably the cause of the shallow depression noticeable around the outer foot of the Ring Barrier.

At a later stage small lava domes rose near the centre of the Ring, and from these, tongues of dense, dark olivine basalt flowed out. The supply was so limited that seldom did they reach the Ring Barrier (Fig. 17c).

Almost concurrently with this effusion of dense olivine lava, an explosive phase took place, which created the smaller scoria and cinder cones, for there is evidence in the scoria pits of this lava being intercalated between layers of scoria. The last chapter in the history of Porndon was the explosion which formed Mount Porndon, an eruption which by its steadily diminishing intensity, formed a high conical peak without a crater (Fig. 17d).

## **V. Byaduk.**

### *(a) Lava Flows.*

Surrounding Mount Napier (1,453 feet), which is the source of the lava flows here described, there is an extensive area covered by sheets of basalt at a high level. From this thick widespread accumulation, there flowed considerable quantities of basalt into former river valleys which drained the Napier area. Three of these valleys, the Harman valley, Scott's Creek, and Weerangourt Creek, all now partially filled with basalt, occur in the neighbourhood of Byaduk, but only the Harman valley, which drains to the west into Lake Condah, is dealt with in this paper (Fig. 18). It is a young valley in Cainozoic limestone which underlies partially or wholly decomposed basalt that covers considerable areas in this district. The width of the Harman valley varies from 300 yards to half a mile.

There is no surface stream, the whole drainage taking place in or under the basalt. The jointed and broken nature of the surface rock provides an easy access for surface water into subterranean channels. In all the lava-filled valleys of this district, the same phenomenon occurs, i.e., the drainage of the area through underground channels. In Scott's Creek valley, adjacent to the Harman valley, a stream of considerable size flows alternately above and below the lava surface. In Harman's valley the stream does not appear on the surface at all until the valley widens out at Wallacedale, and there many springs unite to form a creek flowing into Lake Condah.

The lava flowing down the Harman valley completely blocked Scott's Creek and the Lyne, which were tributary streams. In

the latter the stream, on reaching the lava which blocked the outlet, disappears into and underneath the wide open joints of the basalt. There is no sign of swamp deposits upstream from the barrier. The lava barrier across the junction of Scott's Creek and the Harman valley resulted in the formation of a swamp or lake, and in this water-logged area sediment and vegetation accumulated. This deposit has now been drained, and an exceedingly rich stretch of land known as "The Louth," has been made available for cultivation. At the western end of "The Louth," in the neighbourhood of Christie's selection, the Harman valley becomes very wide, and the lava flow, instead of being confined between comparatively steep valley sides 300 yards or less apart, widens into a sheet about  $1\frac{1}{2}$  miles in width.

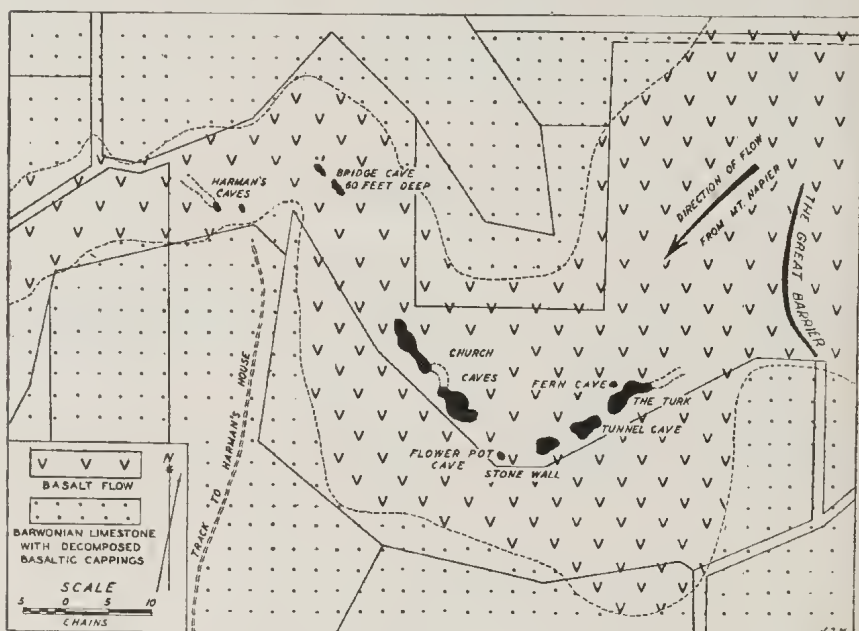


FIG. 18.—Caves and collapsed caverns in Harman's Valley, Byaduk.

(b) *The Barriers.*

Much of the surface of the basalt in the Harman valley is made so rough by deeply fractured basalt barriers and depressions, that it can be traversed only with great difficulty. The barriers or ridges are of two distinct types—single transverse barriers and twin barriers longitudinal to the direction of the flow.

Twin barriers are seen in several places on the well defined lava flow at Byaduk North, while near Wallacedale, there is an example, diagrammatic in its perfection. The Byaduk twin



barriers are about 400 yards in length. The barriers stand from 10 to 20 feet above the valley floor, and are separated from each other by 40 or 50 feet at the summits. Each ridge has columnar jointing perpendicular to the surface slopes, and in every instance the columns along the crests of both ridges are displaced to form V-shaped trenches 10 to 12 feet in depth (Plates XVII.c, XVIII.A).

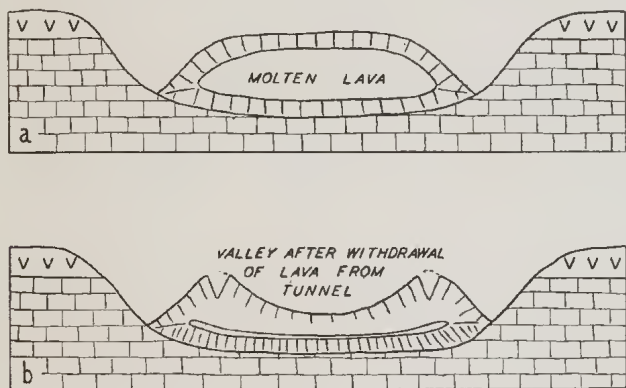


FIG. 19.—Section of basalt flow from Mt. Napier in Harman's Valley, Byaduk. a. Early stage. b. Showing present development of twinned breached barriers.

It is evident that the molten basalt beneath the solidified crust of an individual lava tongue occupying only a part of the total width of the basalt covered valley (Fig. 19A), was withdrawn probably through a break at the snout of the flow, and the crust being unsupported, collapsed, but left the solid edges in their original position. As polygonal jointing had at that time already developed, the fractures took place parallel to the sides of the lava tongue, and in this way twin ridges or barriers developed (Fig. 19B).

Barriers transverse to the direction of the lava movement are of different origin. They appear to have been the halting places of the basalt where solidification of the front offered temporary resistance to the pressure of the molten lava within. Crescentic barriers, steep and convex on the down-valley side, were consequently formed above the level of the lava sheet (Fig. 18). When at length the lava escaped at the base of the front of the flow, a deep trench was formed immediately behind the transverse barrier. The formation of this trench caused a fracture along the crest of the barrier. The largest of the transverse barriers occurs near the junction of the Napier lava plateau with the Harman valley. It is 500 yards in length, has a fracture 20 feet



deep along the whole of the crest, and has a trough behind it 45 feet in depth. The edge of the flow behind the trough has two lines of fracture probably caused by the collapse of the trough in front of it (Fig. 20).

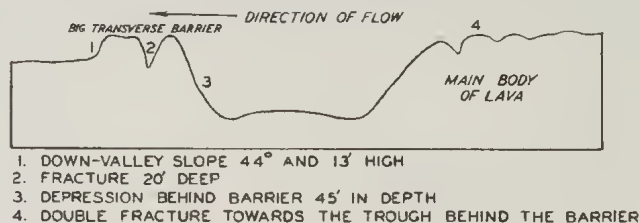


FIG. 20.—Section of great transverse barrier and trough, Harman's Valley, Byaduk.

(c) *The Caves.*

Between Harman's and the big transverse barrier are several caves with vertical sides, up to 60 feet in depth (Fig. 18 and Plate XVII.B). On the floor of each cave is a tumbled mass of columnar basalt. Scoriaceous basalt also is abundant.

Extending from the bottom of the aperture of each cave are one or two large tunnels on whose roofs are exposed the broken ends of prismatic columns. These indicate that the tunnels are not entirely original formations like the caves at Porndon, but have been modified by lava blocks falling from the roof into a tunnel-like cavity at a deeper level. Owing to the difficulty of climbing over the heaps of fallen blocks which are wet and slippery, all the tunnels were not examined along their entire length, but one (Harman's) was explored for about 200 yards, when fallen blocks over the floor prevented further progress. All the tunnel caves inspected showed the same characteristics—floors covered by a jumble of huge rock masses, roofs made of scoriaceous basalt or the broken ends of prismatic columns, generally 20 to 30 feet above the floor, and with a width of 20 to 40 feet.

The caves are of various sizes. One of the Bridge Caves is 60 feet deep, 130 feet long, and 70 feet wide, while the Turk Cave is 500 feet in length, 80 feet wide, and it is connected by a natural tunnel with Tunnel Cave, 260 feet long and 100 feet wide. Caves such as Fern Cave and the Flower Pot, with their pretty shrubs and trees that reach the surface, are small compared with those mentioned above, being less than 60 feet in diameter. Besides the caves and tunnels mentioned in the text and shown on the map, there are many more, some of which are tiny pits with vertical sides, and others, areas suffering collapse.

The sides of the caves reveal much of the volcanic history of the valley. Six flows are exposed, each averaging about 10 feet

in thickness. In one of the caves is seen a venter of lava from a later flow, covering the fractured edge of an earlier one. This suggests that at the time the caves were formed or partly formed, at least one of the later flows had not completely solidified.

An examination of the map (Fig. 18) shows that the tunnels and caves lie along a well defined line which probably represents the course of the stream formerly draining the Harman valley. The facts available, such as at Harman's Cave, suggest that the first lava flow from the Napier plateau into the Harman valley was very thick. It overwhelmed the stream, and in doing so, created enormous quantities of steam which, imprisoned within the lava, caused the development of many steam blisters or cupolas beneath a thin crust. After the formation of the blisters or cupolas, the onflow of the molten lava, by bursting through the crust at the snout of the flow, developed lava tunnels. Later outpourings of basalt flowed around these hollow hills and ridges, until the surface presented a relatively uniform appearance. The last eruptions flowed right across the steam blisters. At length the thin crust of the caverns gave way, and then the vertical prismatic jointing of the upper flows offered little resistance to a general collapse into the caverns below (Fig. 21). As before stated, it is evident that collapse took place before solidification of the upper flows was complete.

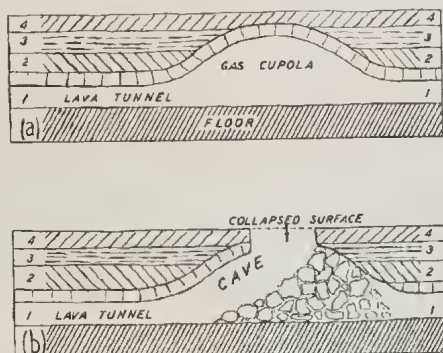


FIG. 21.—Harman's Cave, Byaduk. a. Development of gas cupola, lava tunnel, and later basalt flows. b. Formation by collapse of surface at apex of gas cupola.

#### (d) Steam Blisters.

At the junction of the Harman valley and Scott's Creek, the lava sheet is about  $1\frac{1}{2}$  miles in width. The surface is generally flat, but on the southern side, about fifty isolated basalt cones project spectacularly above the plain. They are from 20 to 30 feet

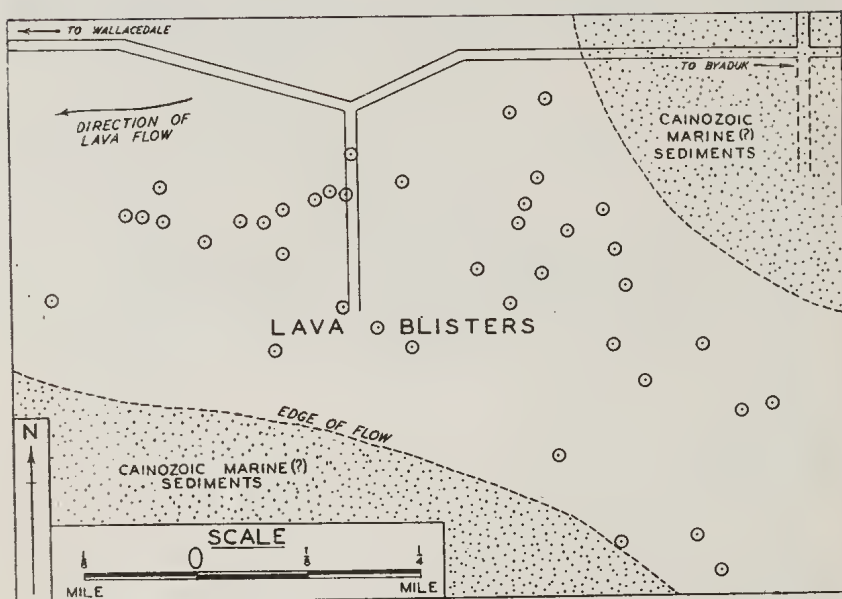


Fig. 22.—Plan showing lava blisters near Christie's, Byaduk.

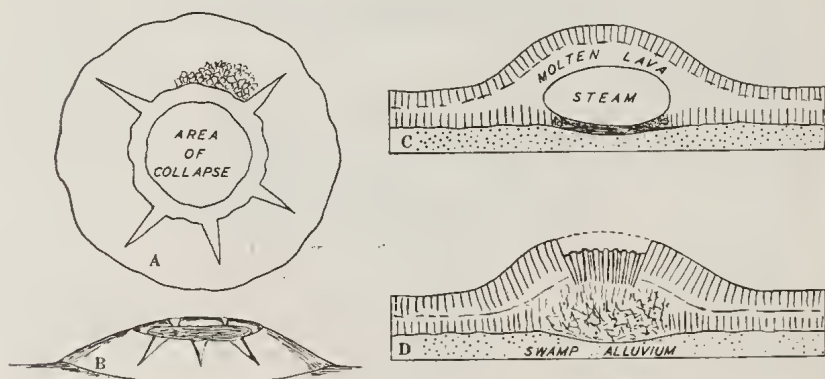


FIG. 23.—Basalt blister, near Christie's, Byaduk. A. Plan showing central collapse. B. Profile sketch showing radial cracks. C. Early stage of development by steam from swamp. D. Present stage after gas explosion, showing central collapse.

in height, and about a chain in diameter (Plate XVIII.B, Fig. 22). That they formed part of the original surface is shown by the continuity of the prismatic jointing from the plain to the sides of the cones. Columnar jointing is strikingly fresh and perfect over the whole surface of these knolls, and scoriaceous or ropy structure is either absent or rare. All the columns are vesicular towards the surface. An examination of these basalt cones reveals that every one is severely fractured. Several radial fractures from 1 to 4 feet in width and about 6 feet in depth, are found on every knoll, and most have also one or more concentric fractures on the upper half. On the crest of each cone is a basin-like depression (Fig. 23A), in the centre of which there is sometimes a small deep hollow (Fig. 23B), and sometimes a conical pile of columnar boulders. The interior of none of the knolls has been fully exposed, but the gaping joints which penetrate them give one the impression that the cones are hollow.

From a distance these low lava domes appear to be centres of eruption, but a closer inspection disposes of that suggestion. It seems probable that each is a steam blister. The lava from the Harman valley, flowing as a fairly thin sheet into a marshy flat on which were isolated pools and quantities of swamp vegetation, would imprison huge steam bubbles. These probably lifted the solidifying surface, and formed cones such as are seen there now (Fig. 23c). That the surface was solid when the cones were formed is shown by the concentric and radial fractures that occur on the surfaces of all the knolls. This suggests that the steam was imprisoned in the plastic lava beneath the contracting crust. As the prismatic joints perpendicular to the cooling surfaces penetrated deeper and deeper with continued cooling, the resistance to the pressure of the steam within slowly decreased. Eventually the formation of the prismatic columns weakened the crust so much that the steam was able, by a slight explosion, to burst open the top of the cones and escape, leading to the partial subsidence of the centre of the arch (Fig. 23D).

## VI. The Age of the Basalts.

Neither the age of the surface features of the Newer Basalts in the areas described above, nor the period of time during which vulcanicity remained active, can be determined with anything like precision.

In the Porndon-Corangamite area the slightly earlier explosive phase of Vaughan's Island was followed by the main effusive stage during which some evidence of contemporaneous tuffs has been recorded. It is certain, however, that the main explosive phase terminated the activity, as the scoria cones overlies the basalts at Porndon, Red Rock and Alvie, although a thin basalt



flow is interbedded with scoria in one of the scoria pits of Mount Porndon. In the scoria pits at Alvie, Mr. D. J. Mahony, about 14 years ago, obtained a mineralized fragment of a bone believed to be from a kangaroo [personal communication]. If the identification is correct, it would suggest that the scoria may be as old as Pleistocene, if the bone was from an extinct kangaroo. We have, however, no definite evidence as to when such a marsupial became extinct. The scoria fragments in this and other pits have an iridescent lustre and an extremely fresh appearance. Most of the basaltic barriers appear to have suffered scarcely any erosion, and on some of them the original tachylytic selvage is still preserved. No noticeable topographical changes appear to have occurred in this district since volcanic activity ceased. In the Byaduk area, too, the basalts, whose surface features are fresh and remarkably preserved, partly occupy valleys whose characters seem to have otherwise remained unmodified since the lava poured down them from Mount Napier.

In this respect the Newer Basalts of Western Victoria seem to be much younger than those near Melbourne, which are referred to the same period. In the latter district, valleys up to nearly 200 feet in depth have been excavated by streams since the basalt flows formed the lava plains near Melbourne.

The lack of subsequent erosion and the fresh appearance of both basalt and scoria in the areas described in this paper, are consistent with the possibility that the volcanic activity occurred within geologically recent times. In addition, it seems to be possible, if not probable, that the volcanic activity in the Porndon area was restricted to a very limited period, such as a few years or even less. The evidence cited in the body of the paper suggests that the formation of the two basaltic plateaux, the lava tongues running into Lake Corangamite, and the somewhat later outpouring of the basalt of the Porndon Ring, all belonged to a single phase of eruptivity during which, while a crust solidified, the greater part of the basalt from the thick sheet remained molten and mobile.

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## Explanation of Plates.

### PLATE XII.

- (a) Collapsed craters of Red Rock, Lake Corangamite with lava tongues, Vaughan's Island on further side of lake, and Mt. Porndon in background.
- (b) Inverted conical sinks due to subsidence of basalt crust, Prince's Highway, near Stonyford.
- (c) Lava tongues with humped surface, Lake Corangamite.

### PLATE XIII.

- (a) Sloping edge of basalt flow. Prismatic columns at right angles to the surface, Dreeite.
- (b) Baked columnar tuff at eastern edge of barrier in contact with basalt with tachylytic selvage, 102 mile post west of Melbourne, Prince's Highway, 1 mile west of Pirron Yallock.
- (c) Small fold in basalt crust, near McGarvie's, Corangamite.

### PLATE XIV.

- (a) Air photograph of Stony Rises, about 1 mile S.-E. of Stonyford. Meandering barriers and valleys in centre, basalt plain to the north, Pirron Yallock Creek to the south.
- (b) Mount Porndon and Ring Barrier, looking east.
- (c) Breached barrier, Dreeite.

### PLATE XV.

- (a) Gas explosion crater, near Porndon Caves.
- (b) Breach, 23 ft. 6 in. deep in barrier, Dreeite.
- (c) "Pseudo breached" barrier, vesicular basalt eroded from the crest of the barrier, near McVean's Springs, Lake Corangamite.

### PLATE XVI.

- (a) "Squeeze up" of basalt through transverse joints of a barrier, near McGarvie's, Corangamite.
- (b) Internal fractured edge of Ring Barrier of Mount Porndon.
- (c) External steep slope of Ring Barrier of Mount Porndon.

## PLATE XVII.

- (a) The south-east cave near Mount Porndon.
- (b) Church cave, Byaduk
- (c) Breached edge of basalt flow, between Christie's and Lake Condah, near Byaduk.

## PLATE XVIII.

- (a) Breached edges of basalt flow, between Christie's and Lake Condah, near Byaduk.
- (b) Basalt blisters, near Christie's, Byaduk.



(a)



(b)



(c)





(a)



(b)



(c)







(a)



(b)



(c)





(a)



(b)



(c)







(a)



(b)



(c)





(a)



(b)



(c)





(a)



(b)





[PROC. ROY. SOC. VICTORIA, 49 (N.S.), PT. II., 1937.]

ART XVII.—*Ecological Studies in Victoria—Part V. Red Box-Red Stringybark Association.*

By R. T. PATTON, D.Sc., D.I.C., M.F., F.R.H.S.

[Read 11th November, 1936; issued separately 19th July, 1937.]

The two trees, Red Box (*Eucalyptus polyanthemus*) and Red Stringybark (*E. macrorrhyncha*) occur together in many parts of the State, accompanied by the Long-leaved Box (*E. elaeophora*), but owing to the more conspicuous characters of the two former, their popular names have been united to designate this particular association. It is found on both sides of the Dividing Range, and extends into East Gippsland, but in the latter area it is not strongly developed although the individual species are fairly widespread. The three dominants are frequently associated with Red Ironbark (*E. Sideroxylon*) which, although it has a wide distribution, is more restricted than the other three. On the lower elevations of the northern slopes of the Dividing Range, Red Ironbark united with Grey Box (*E. hemiphloia*) and White Ironbark (*E. leucoxylon*) to form the Box-Ironbark forests, but quite commonly it forms a pure forest itself. Red Ironbark is therefore not considered to be a member of the Red Box-Red Stringybark Association, but when it occurs it indicates that conditions are becoming unfavorable for the development of this association. Another eucalypt, Yellow Box (*E. melliodora*) may also occasionally be present, but it also indicates a change in soil condition.

This association occurs freely on both palaeozoic sedimentary and igneous rocks in widely separated areas. The dominants are always characteristic, and judged by these alone, they form a definite forest type. However, the various occurrences of this association are so distributed and separated from one another that it may subsequently be found that the ground vegetation varies considerably. This is of some importance in view of Cajander's (2) theory of forest types in which the basis of classification of forest land is the plant association, but independent of the species of trees. Cajander says, "all those stands are referred to the same forest type the vegetation of which . . . is characterized by a more or less identical floristic composition . . . ."

Besides passing into the Box-Ironbark forest type, at other times this association passes gradually into grassland. There is always present in the ground flora a large number of grass species, and as the trees become wider and wider apart, so the grasses

become more and more dominant, and the other associated species gradually decrease. The forest passes into Savannah or Steppe.

The Red Box-Red Stringybark Association has only been intensively studied in the Greensborough-Diamond Creek area, but observations have been made from the Plenty River on the west to Warrandyte on the east, and northwards to Pantou Hill. This area forms part of the Nillumbik Peneplain of Jutson (7) and Junner (6), by whom it has been very fully dealt with. Hills (5) considers that the Nillumbik Peneplain is best regarded as a modified pre-Older Basaltic Terrain which was of low relief. The area consists in the main of openly folded Silurian sediments, together with, on the higher levels, patches of Older Basalt and some gravels. Neither of these latter geological formations has been included in this study. The basalt areas have an entirely different soil and are intensively cultivated. The gravel deposits are very shallow, and have been largely removed for commercial purposes. After, or during, the extrusion of the Older Basalt (5), which is probably of Oligocene age, the land became partly depressed, and on it were laid the sands and gravels which constitute the coastal plain south-east of Melbourne, on which is developed the Cheltenham Flora (10). Depression continued until the Kalimnan period (Lower Pliocene), and then uplift occurred. Junner (6) considers the elevation was slow, and according to Hills (4) amounted to hundreds of feet only. These elevated areas are still lower than the pre-Older-Basaltic Divide.

A large proportion of the original forest has been replaced by orchards, the fruit grown being apples, pears, peaches, plums, and to some extent, lemons. The remaining area has been subject to human interference, chiefly confined, however, to the felling of the trees, which have again grown and formed forest. The soil has not been interfered with, and, apart from the periodic felling of the trees, the areas are practically left alone. Only occasionally are old trees met with, and these indicate the nature of the original forest. There is frequently a great difference between the degrees of development of the lower shrub stratum owing to the variation of density in the crown cover. Where the crowns meet in close canopy the vegetation is sparse, and this is also found on slopes facing the north.

### Physiognomy.

The Red Box-Red Stringybark Association is characteristically xerophytic, and aptly fits the description by Schimper (16) of sclerophyllous forest. The trees are small, from 20 to 30 feet high, with short trunks and wide crowns which allow ample light to reach the forest floor. The leaves are coriaceous, and the trunks clothed with a thick persistent bark. All the three dominants have drooping leaves. Although there are several species of tall shrubs present, they occur very sparsely and do not affect the physiognomy. The under-shrubs are abundantly

present, both as regards individuals and species. These possess generally small leaves and narrow stems, as already seen in the Cheltenham Flora (10). The ericoid leaf is found in Leguminosae, Proteaceae, Compositae, and Epacridaceae. Between the shrubs are tufts of perennial grasses, which mostly elevate their inflorescences late in the spring or early summer. The shrubs and grasses together do not form a complete soil cover. Except at flowering time the grasses, although plentifully present, are not conspicuous. Both grasses and shrubs are markedly xerophytic.

Perhaps the most remarkable feature of the association is the large number of species present that perennate underground during the adverse period. This is, of course, particularly the case with Liliaceae and Orchidaceae, both of which are strongly represented. But besides these there are several other families, as Ranunculaceae, Droseraceae, Geraniaceae, and Compositae, that have swollen underground parts. Others, as *Helichrysum scorpioides* and species of *Erechthites*, arise from the underground part of the previous year's shoot.

Lianes are well represented, although they have only rather small shrubs for support. None of these ascend the dominant trees. As with the other growth-forms, the lianes belong to widely differing families, as Liliaceae, Ranunculaceae, Droseraceae, Pittosporaceae, Leguminosae, and Polygalaceae.

In Table I. are given the numbers and percentages of each life form occurring in the Red Box-Red Stringybark Association. The life forms are based upon the system of Raunkaier (15), and modified by Braun Blanquet (1). The life forms of Parasites and Lianes have been added. Macrophanerophytes are those plants with growing points above 2 metres from the ground, Nanophanerophytes from 0.25 metres to 2 metres, Chamaetophytes with buds on surface of ground or up to 0.25 metres. Hemicryptophytes have dormant buds in the surface of soil. Geophytes perennate wholly below ground. Therophytes are annuals.

TABLE I.—CLASSIFICATION OF THE LIFE FORMS OF THE RED BOX-RED STRINGYBARK ASSOCIATION.

Life form.				Number.	Percentage.
					%
Macrophanerophytes	..	..	..	9	5.7
Nanophanerophytes	..	..	..	19	11.9
Chamaetophytes	..	..	..	24	15.0
Hemicryptophytes	..	..	..	33	20.6
Geophytes	..	..	..	57	35.6
Therophytes	..	..	..	10	6.2
Lianes	..	..	..	5	3.1
Parasites	..	..	..	3	1.9
Total	..	..	..	160	100.0

As Geophytes do not affect the physiognomy but chiefly only the spring aspect of the association, in such a classification, therefore, undue importance is given to them, and this is due in a great measure to the large number of species of both Orchidaceae and Liliaceae. The classes Chamaetophyte and Hemipterophyte are frequently very difficult to determine.

### Composition.

The association is characterized by the richness of its flora in families, genera, and species (Table IV.). There is a strong representation of characteristic Australian genera, but an outstanding exception is *Casuarina*. Over a wide area, only a single specimen of *Casuarina suberosa*, and one of *C. stricta* have been seen, and they are therefore not regarded as members of this association.

The family Myrtaceae is only represented by the dominants of the association, all being species of *Eucalyptus*. These five species (Table IV.) belong to four sections of the genus, and therefore cannot be regarded as being intimately related to one another. This lack of close relationship between species of a genus found in any particular association appears to be a characteristic feature. In other associations dominated by species of *Eucalyptus*, as Box-Ironbark (*E. hemiphloia*, *E. Sideroxylon*), and Messmate-Peppermint (*E. obliqua*, *E. australiana*), this lack of intimate relationship is again shown, for all these species belong to different sections of the genus. Even species that have the same growth-form may exhibit other marked differences. Thus the three species of *Drosera*, which are all Geophytes, represent three types of acrial growth. *Drosera Whittakeri* forms only a rosette, and the flower stalks are devoid of leaves, *D. auriculata* has an erect flowering shoot with auriculate stem leaves, while *D. Menziesii* is a climbing plant with rounded peltate leaves on the stem. *D. peltata*, which is very similar to *D. auriculata*, has not been found in this association, but does occur in the adjoining Messmate-Peppermint Association. The three commonly occurring species of *Helichrysum* also differ from one another very materially, and cannot be considered to be closely related in any way. *H. scorpioides* perennates below ground, and its basal leaves are large and mesophyllous. The flowering stalk is terminated by a large yellow head. *H. semipapposum* is semi-herbaceous, with fairly long, linear, woolly leaves, and the capitula are moderately small and crowded together. *H. obcordatum* is shrubby, with small leaves glabrous above, and very small crowded capitula. The fourth species, *H. apiculatum*, is rare, but it is very distinct from the others. Similar striking differences may be seen between species of *Acacia*, *Pultenaea*, *Viola*, and *Brachycome*.



This frequent lack of intimate relationship between species of a genus is paralleled by the lack of close relationship that exists generally between the species of any association, due to the fact that they belong to widely differing genera and families. It has been previously indicated (11) that it is usual for a large number of genera to be represented by a single species, and, therefore, the average number of species per genus for any association is small. In this particular association there are no less than 80 such genera. Some of these are very large, and are prominent in Australian vegetation. Of the fifteen largest genera in Victoria (12), four of them—*Prasophyllum*, *Grevillea*, *Goodenia*, and *Leucopogon*—are represented here by a single species. Among the fifteen largest genera in the Commonwealth (12) *Prasophyllum* does not occur, but *Stylidium* is included, and has in this association a single species. There are only two genera, *Olearia* and *Carex*, which occur among the fifteen largest genera in Victoria which are not represented.

The family Orchidaceae is, among other features, remarkable in this association for the number of genera and species (Table IV.), and the extraordinarily large numbers of individuals present. Three genera, *Pterostylis*, *Prasophyllum*, and *Caladenia*, occur among the fifteen largest genera in Victoria, and all are represented here. The family Orchidaceae occurs among the ten largest families in both Victoria and the Commonwealth. The species are only above ground during the period of the year when soil moisture is abundant, from late autumn to late spring. The only exception is *Dipodium punctatum*, which is saprophytic, and which flowers during the hottest period of the year. This orchid is also the largest, with the possible exception of *Thelymitra grandiflora*. Some species of Orchidaceae are exceedingly gregarious, in particular *Corysanthes diemenica* and *Cyrtostylis reniformis*. Both of these form small societies to the exclusion of other species, and both tend to occur at the bases of large trees. A remarkable feature of these societies is that very few of the individuals produce flowers, which is in strong contrast with the free flowering of such scattered species as *Microtis porrifolia* and *Glossodia major*.

The genus *Pterostylis* is represented by the largest number of species, and probably also produces the greatest number of individuals, which may be locally abundant as *P. nutans*, or somewhat isolated as *P. longifolia*. The members of the genus may conveniently be divided into two groups, those with and those without a rosette. Those with a rosette exhibit a remarkable degree of variation within very narrow limits of certain characters. *P. parviflora* flowers soon after the autumn rains and before the appearance of the rosette, which is produced on another shoot towards the close, or soon after flowering. The

flowering shoot draws upon the reserve food material produced during the previous year. Before winter appears the rosette of *P. nutans* which flowers during the winter. This species has a remarkably long flowering period. Similar to *P. nutans* in producing the rosette before flowering and retaining it until after flowering are *P. curta*, *P. nana*, and *P. pedunculata*. The rosettes of these species begin to wither during September. The last to bloom is *P. pusilla*, which produces its first flowers during October, when its rosette has already withered. In this latter case the production and withering of the rosette precede the flowering period.

In *Caladenia* the species present are all similar vegetatively in having a single, linear to linear-lanceolate, basal leaf, and in having a small bract along the usually singly terminated flowering stem, but they differ appreciably from one another in the form and colour of their flowers. *C. carnea* is pink, while *C. coccinea* is blue. In *C. dilatata*, which is very common, there is an extravagant development in the length of the perianth parts except the labellum, which is much fringed. There is no close relationship between the two former species and *C. dilatata*, but this latter is closely connected with *C. cardiochila*, which is very rare. Closely related to these two, and differing but slightly from them, is *C. Patersonii*, which has not been found by the author in the Red Box-Red Stringybark Association, but which is abundant in the adjoining Messmate-Peppermint Association. It may be here noted that the recognition of such closely allied forms as *C. dilatata*, *C. cardiochila*, and *C. Patersonii* as separate species is frequently the cause of disagreement among systematists. Of these three, Mueller (9) recognized *C. Patersonii* only. Similarly, of the two closely allied, *C. testacea* and *C. carnea*, Mueller only recognized the latter.

The species of *Acacia* occurring in the Red Box-Red Stringybark Association are very distinctive, and are different from those occurring in other Victorian Associations, in which there is comparatively little overlap in regard to species. In Table II. are given the species of *Acacia* in various associations, together with the sections of the genus to which they belong.

In Table II. it will be noted that all the *Acacias* in the Red Box-Red Stringybark Association belong to the same section of the genus, but they are nevertheless very distinctive. Although the genus *Acacia* is a very large (Table III.) and widely distributed one, yet its representation in each of the associations given is not large. This is also shown to be the case (Table III.) with other widespread genera which are represented in the Red Box-Red Stringybark Association. The number of species in the genus is taken from Willis (17), and the number in Victoria from Ewart (3).

TABLE II.—DISTRIBUTION OF SPECIES OF ACACIA IN VARIOUS ASSOCIATIONS.

Section of Genus.	Cheltenham Flora.	Coastal Dunes.	Fern Gully.	Red Box-Red Stringybark.	Messmate. Peppermint.
<i>Uninerves</i>	<i>armata</i>	..	..	<i>armata</i>	..
	..	..	..	<i>acinacea</i>	..
	..	..	..	<i>diffusa</i>	..
	..	..	..	<i>juniperina</i>	..
	..	..	..	..	<i>leprosa</i>
	..	..	..	..	<i>myrtifolia</i>
	..	..	..	..	<i>stricta</i>
	<i>suaveolens</i>	..	..	..	..
	..	..	..	<i>vomeriformis</i>	..
<i>Plurinerves</i>	..	..	<i>melanoxydon</i>	..	<i>melanoxydon</i>
<i>Juliflorae</i>	..	..	..	..	<i>longissima</i>
	<i>Oxycedrus</i>	..	..	..	..
	..	<i>Sophorae</i>	..	..	..
	..	..	..	..	<i>verticillata</i>
<i>Bipinnatae</i>	..	..	<i>dealbata</i>	..	<i>dealbata</i>

TABLE III.—NUMBER OF SPECIES OF SOME WIDESPREAD GENERA IN VARIOUS ASSOCIATIONS.

Genus.	Number of Species in—						
	Genus.	Victoria.	Cheltenham.	Coastal Dunes.	Fern Gully.	Basalt.	Red Box Red Stringybark.
<i>Acacia</i> ..	500	77	3	1	2	0	5
<i>Helichrysum</i>	350	23	2	1	..	1	4
<i>Leucopogon</i> ..	130	18	1	1	..	..	1
<i>Stipa</i> ..	120	18	1	..	..	3	2
<i>Goodenia</i> ..	100	19	1	..	..	1	1
<i>Pimelea</i> ..	80	22	3	..	..	3	2
<i>Lepidosperma</i>	40	16	1	1	1	..	1

From the above table it will be seen that there is a closer agreement between the Cheltenham Flora and the Red Box-Red Stringybark Association as regards the distribution of the genera than between any of the other associations.

## TABLE IV.—COMPOSITION OF FLORA OF RED BOX-RED STRINGYBARK ASSOCIATION.

## RED BOX-RED STRINGYBARK ASSOCIATION.

## PTERIDOPHYTA

## POLYPODIACEAE

*Cheilanthes tenuifolia*

## SPERMATOPHYTA

## ANGIOSPERMAE

## MONOCOTYLEDONAE

## GRAMINEAE

*Agropyrum scabrum*  
*Calamagrostis filiformis*  
*C. quadriseta*  
*Chloris truncata*  
*Danthonia pallida*  
*D. penicillata*  
*D. semiannularis*  
*Dichelachne crinita*  
*D. sciurea*  
*Poa caespitosa*  
*Stipa mollis*  
*S. pubescens*  
*Themeda triandra*

## CYPERACEAE

*Gahnia radula*  
*Lepidosperma filiforme*

## JUNCACEAE

*Lucula campestris*

## LILIACEAE

*Anguillaria dioica*  
*Bulbine bulbosa*  
*B. semibarbata*  
*Burchardia umbellata*  
*Chamaescilla corymbosa*  
*Dianella revoluta*  
*Dichopogon strictus*  
*Lomandra filiformis*  
*L. longifolia*  
*Thysanotus Patersonii*  
*Tricoryne elatior*  
*Xanthorrhoea minor*

## AMARYLLIDACEAE

*Hypoxis glabella*  
*H. pusilla*

## ORCHIDACEAE

*Acianthus exsertus*  
*Caladenia cardiochila*  
*C. carnea*  
*C. coerulea*  
*C. dilatata*  
*C. testacea*  
*Calochilus Robertsonii*  
*Corysanthes diemenica*  
*Cyrtostylis reniformis*  
*Dipodium punctatum*  
*Diuris longifolia*  
*D. maculata*  
*D. pedunculata*

ORCHIDACEAE—continued.

- D. sulphurea*
- Eriochilus cucullatus*
- Glossodia major*
- Microtis porrifolia*
- Prasophyllum nigricans*
- Pterostylis alata*
- P. barbata*
- P. curta*
- P. longifolia*
- P. nana*
- P. nutans*
- P. parviflora*
- P. pedunculata*
- P. pusilla*
- P. revoluta*
- Thelymitra aristata*
- T. antennifera*
- T. carnea*
- T. ixioidea*
- T. grandiflora*

ARCHICHLAMYDEAE

PROTEACEAE

- Grevillea rosmarinifolia*

SANTALACEAE

- Exocarpus cupressiformis*

LORANTHACEAE

- Loranthus pendulus*

RANUNCULACEAE

- Clematis microphylla*
- Ranunculus lappaceus*

LAURACEAE

- Cassythia glabella*

DROSERACEAE

- Drosera auriculata*
- D. Menziesii*
- D. Whittakeri*

CRASSULACEAE

- Crassula Sieberiana*

PITTOSPORACEAE

- Billardiera scandens*
- Bursaria spinosa*

LEGUMINOSAE

- Acacia acinacea*
- A. armata*
- A. diffusa*
- A. juniperina*
- A. vomeriformis*
- Bossiaea prostrata*
- Daviesia corymbosa*
- Dillwynia cinerascens*
- D. floribunda*
- Glycine clandestina*
- Hardenbergia monophylla*
- Hovea heterophylla*
- Indigofera australis*
- Kennedya prostrata*
- Platylobium obtusangulum*
- Pultenaea pedunculata*
- P. Gunnii*



- ROSACEAE  
*Acaena ovina*  
 GERANIACEAE  
*Geranium pilosum*  
 OXALIDACEAE  
*Oxalis corniculata*  
 LINACEAE  
*Linum marginale*  
 RUTACEAE  
*Correa rubra* var. *virens*  
 POLYGALACEAE  
*Bredemeyera volubile*  
 EUPHORBIACEAE  
*Poranthera microphylla*  
 TREMANDRACEAE  
*Tetralitea ciliata*  
 STACKHOUSIACEAE  
*Stackhousia monogyna*  
 GUTTIFERAE  
*Hypericum gramineum*  
 VIOLACEAE  
*Viola betonicifolia*  
*V. hederacea*  
 THYMELAEACEAE  
*Pimelea curviflora*  
*P. humilis*  
 MYRTACEAE  
*Eucalyptus elaeophora*  
*E. macrorrhyncha*  
*E. melliodora*  
*E. polyanthemus*  
*E. Sideroxylon*  
 HALORRHAGIDACEAE  
*Halorrhagis tetragyna*  
 UMBELLIFERAE  
*Daucus glochidiatus*  
*Hydrocotyle laxiflora*  
*H. medicaginoides*  
 METACHLAMIDEAE  
 EPACRIDACEAE  
*Astroloma humifusum*  
*Acrotriche serrulata*  
*Epacris impressa*  
*Leucopogon virgatus*  
*Lissanthe strigosa*  
 LOGANIACEAE  
*Mitrasacme paradoxa*  
 GENTIANACEAE  
*Erythraea spicata*  
*Sebaea ovata*  
 CONVULVULACEAE  
*Dichondra repens*  
 BORAGINACEAE  
*Cynoglossum suaveolens*  
 LABIATAE  
*Ajuga australis*

## SCROPHULARIACEAE

*Veronica gracilis**V. calycina*

## PLANTAGINACEAE

*Plantago varia*

## RUBIACEAE

*Asperula scoparia*

## CAMPANULACEAE

*Lobelia gibbosa**Wahlenbergia gracilis*

## GOODENIACEAE

*Goodenia geniculata*

## BRUNONIACEAE

*Brunonia australis*

## STYLIDIACEAE

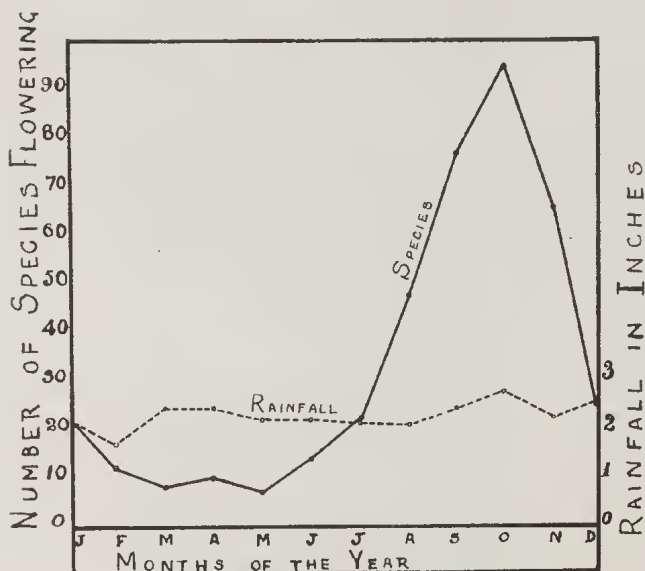
*Stylidium grammifolium*

## COMPOSITAE

*Brachycome decipiens**B. multifida**B. scapigera**Cassinia aculeata**C. longifolia**Craspedia uniflora**Cymbonotus Lawsonianus**Erechthites arguta**E. quadridentata**E. prenanthoides**Gnaphalium japonicum**Helichrysum apiculatum**H. obcordatum**H. scorpioides**H. semipapposum**Helipterum albicans**H. australe**Leptorhynchus squamatus**L. tenuifolius**Microseris scapigera**Millotia tenuifolia**Podolepis acuminata**Rutidosia leptorhynchoides**Vittadinia triloba***Environment.***(a) Climate.*

The area between Greensborough and Diamond Creek lies within the railway suburban area of Melbourne, as do also Cheltenham and St. Albans. There is but little difference between the general climatic conditions of these three areas, and therefore no discussion of climatic factors other than given by Patton (10) and (11) need be mentioned. In Figure 1. are given the numbers of species flowering each month, and also the rainfall for Greensborough. It will be seen that the peak of flowering is in October, as was the case in the Cheltenham and in the Basalt Floras, and that there is a sudden fall from October to December. The soil steadily becomes drier through summer and autumn, and the

plants suffer a periodic drought. During the autumn of 1936, the moisture content sank to 2.8 per cent., but approximately 10 per cent. of moisture is required for germination of garden seeds. However, at this latter moisture content, germination is exceedingly slow. During the early period of the year, the limit



of endurance to drought is reached, and many plants may be seriously affected. In the present year, 1936, there was a very dry period, and *Epacris impressa* and *Astroloma humifusum* died extensively. In numerous plants of *Acacia diffusa* branches were dead. Although no plants of either *Correa rubra* var. *virens* or *Billardiera scandens* were found dead, both had the leaves much curled and were pale in colour. The severity of the dry period of 1936 was also indicated by the death of numerous forest trees between Fern Tree Gully and Ferny Creek. During the autumn of the years 1923, 1927, and 1932, plant life has suffered severely in various parts of the State from lack of moisture in the soil. The actual and average rainfall for the summer and autumn months for Melbourne is given for the years 1923, 1927, and 1936, in Table V. During February, 1932, there was widespread destruction of plant life on the northern end of the Buffalo Plateau, and this was followed by a severe bushfire.

It has previously been pointed out (13) that such periodically recurring dry periods must have an important effect on vegetation. A slight decrease in the annual average rainfall would eliminate a number of species, for undoubtedly several are at the limit of endurance. On the other hand, if there was an increase in the annual rainfall, such species as *Pteridium aquilinum* and *Acacia*

TABLE V.—MONTHLY RAINFALL FOR MELBOURNE FOR CERTAIN DRY YEARS COMPARED WITH AVERAGE.

Month.				Actual Rainfall Points.			Average Points.
				1923.	1927.	1936.	
January	..	..	..	99	60	130	186
February	..	..	..	61	75	58	175
March	..	..	..	33	134	52	226
April	..	..	..	..	57	430	220

*myrtifolia*, which at present occur where this association passes into Messmate-Peppermint, would gain entrance. The essential environmental factor which separates these two associations appears to be annual rainfall.

### (b) Soil.

The controlling factor of the vegetation of this area as compared with that of the Tertiary Sands and Basalt areas is the geological formation. The bedrock outcrops at the surface in places, but generally it produces a shallow clayey soil which may contain a very large proportion of small stones. Soil may be defined ecologically as the medium in which roots find themselves. Lundergardh (8) defines soil as that part of the earth's crust that is clothed with plants. Both definitions include mud on a lake floor or the joint planes of a rock mass, and are widely different from the agricultural viewpoint, which conceives of a certain depth of material consisting of particles of a fineness less than 2 mm. diameter. This latter conception fails entirely to meet the needs of the ecologist. Several samples of the soil from the Red Box-Red Stringybark Association have shown that the particles above 2 mm. form more than 50 per cent. of the mass. Such large particles are important in the mechanical composition of the root environment. The soil varies so much that it is useless to give any profile of it. At times a feeble profile is developed, but is never pronounced, as in the Cheltenham Flora (10), or in the Basalt (11).

Although the area on which the Red Box-Red Stringybark is hilly, the total elevation is small, amounting to a few hundred feet only, at the highest point, and therefore insufficient to make any marked difference in the climatic conditions. Since the rainfall is similar to that of the other associations in the metropolitan area, the differences between the three major associations cannot be ascribed to this factor.

### Discussion.

Within the area of the Nillumbik Penplain there are patches of Older Basalt and of Gravels. This latter has been mostly removed, and therefore the vegetation has been disturbed. The soil of the Basalt is dark in colour, and is entirely different from

the creamy yellowish clay of the Silurian sediments. It has been devoted to entirely different agricultural pursuits. Yet both the Basalt and the Silurian sediments are at similar elevations, and have been subject to the same climatic conditions. The older Basalt is of Oligocene age, and therefore there has been abundant time for climate to produce similar soils on both the Basalt and the Silurian if climate be the cause of soil differences (14).

The three major geological formations in the metropolitan area, Silurian, Tertiary Coastal Plains, and the Newer Basalt (Pleistocene) have all been exposed to the same climatic conditions for long periods of time, much longer than the time interval for the development of the soil types in Russia, yet each has an entirely different soil. Climate, therefore, cannot be regarded as the factor which has produced such differing types. All three soils, although so different and clothed with very different types of vegetation, are classed together as podzolised soils on a map by Prescott (14). All three have much the same elevation, and therefore this factor cannot be considered to have produced the conspicuous differences. The only outstanding difference in the three areas is the geological formation, and to this factor alone must be ascribed the cause for the occurrence of three such striking plant associations, Grassland, Heath, and Sclerophyll Forest in close proximity to one another. Climate can only break down the rock mass, and cannot influence the final result over wide areas. Climate cannot determine the size of the soil particles, as is shown in the large proportion of sand in the soil derived from the ferruginous sandstones of the Tertiary Plains, or in the large proportion of clay in the soil derived from the Basalt. One cannot conceive of anything but a sandy soil being derived from a sandstone, and of this there are some striking examples in Australia. Nor can one conceive of any plant nutrients being added by climate. The soil resulting from any particular rock can only contain those elements which the disintegrated rock provides. Each of these associations, then, Sclerophyll Forest, Heath, and Grassland, owe their development to the type of rock underlying the area on which they grow.

The differences in the physiognomy of these associations is due to the life forms dominant in each case. Life form is an expression of the relation of the species present to the environment, and a large number of families converge to the same life form. It has already been noted, for instance, that both Lianes and Geophytes are produced from widely differing families. Since particular life forms are found under particular environmental conditions, it may safely be concluded that such forms are particularly adapted to those conditions.

An association is notable for the low number of species per genus, the divergent nature of the families represented, and the domination of certain life forms. All of these three features



are interlocked. The total number of life forms in nature is surprisingly small, and therefore the divergent families must converge on the one life form favorable to the environment, if they are to be represented in any particular association.

It is not suggested that there is an active response on the part of the plant to the environment, but that, since variation is inherent in life itself, and, indeed, may be considered a characteristic equally with growth, appetite, reproduction, irritability, &c., the opportunity for a new variant to occur is when a new environment is presented. Species are natural units with well defined characters, as, for instance, those given in Table II., but if we assume that species are built up by accretions of small differences, then there should be a passage from one species to another in a genus. Or in other words, there should be in general a graduated series of species. This does occur at times, particularly in the genus *Eucalyptus*, as, for instance, in the Stringybark section. In the genus *Caladenia* also there are related species, but it may be reasonably argued that *C. dilatata*, *C. cardiochila*, and *C. Pater-sonii* are merely varieties and not distinct species. The variations that constitute these forms are no doubt heritable, but a heritable variation is insufficient for the establishment of a species.

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[PROC. ROY. SOC. VICTORIA, **49** (N.S.), PART II, 1937.]

ART. XVIII.—*Some Anatomical and Cytological Studies on Fiji Disease of Sugar Cane.*

By E. J. FERGUSON WOOD, M.Sc., B.A.

[Read 10th December, 1936; issued separately 19th July, 1937.]

Fiji disease of sugar cane is considered on the evidence available to be one of the virus group of plant diseases, but differs from all other plant viruses in that the stunting of the plant is accompanied by the occurrence of galls in the stem and leaf, but not, as far as the writer has observed, in the root. McWhorter (5) reports root galls, but in a large number of roots of Fiji diseased cane examined by the present writer no galls were found.

### I. Appearance of the Gall.

Stem galls cause no abnormality in the external appearance of the plant, but, on sectioning, it can be seen by the naked eye that many of the vascular bundles are larger than normal.

Leaf galls, however, protrude on the abaxial surface of the leaf, run parallel with the midrib, and are obviously continuations of individual vascular bundles. Occasionally, two adjacent bundles will form parallel galls, but there is always a line of demarcation showing from which bundle the gall is derived.

The galls therefore are purely vascular, and the course of the vascular bundle is not altered by gall formation. The non-vascular parenchyma is not influenced by gall formation, except that the cells are rather smaller than normal. The number of chloroplasts does not appear to be reduced, so that the darker green colour that is characteristic of the diseased leaves is apparently due to the crowding of the chloroplasts within the cells. The deformation of the leaves is due to the proliferation of cells in the vascular bundles causing a twisting of the parts of the leaf which are not hypertrophied. The dwarfing is no doubt due to the derangement of the metabolic functions consequent on gall formation where the vascular tissues are involved.

### II. Anatomical Structure of the Gall.

A description of the anatomy of the healthy sugar cane leaf is omitted in this paper as it is given fully in a paper by Artschwager (2) and need not be repeated here.

There are five regions in the gall (Fig. 1A):—

1. Protoxylem vessels and lacuna as in healthy tissues.

2. Primary metaxylem vessels, as in healthy tissues, though these may be more or less hypertrophied. In some cases, projections of the lignified cell walls have been observed.

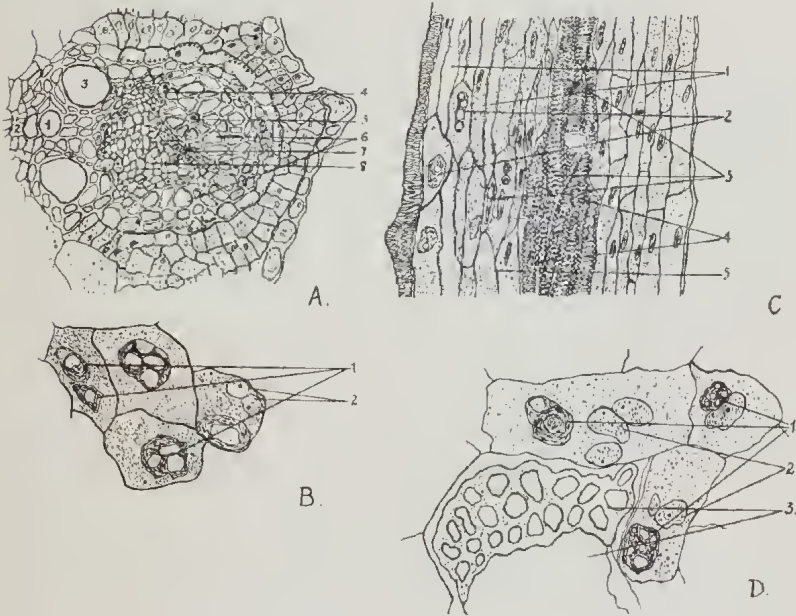


FIG. 1.—A. Transverse section of a gall, showing hypertrophied phloem and xylem, and the position of the pseudoparenchyma adjacent to the pseudotracheids. 1. Protoxylem vessels; 2. Protoxylem lacuna; 3. Primary metaxylem; 4. Partially lignified cell still containing nucleus; 5. Isolated thin walled pseudoparenchyma cell; 6. Pseudotracheidal tissue; 7. Pseudoparenchyma tissue; 8. Phloem. B and D. Pseudoparenchyma cells containing "X" bodies. 1. "X" bodies; 2. Multinucleate tissue; 3. Pseudotracheid. Note that three cells in B have "X" bodies and no nucleus, and all the cells in D contain both bodies and nuclei. C. Longitudinal section through portion of a gall showing stages in the formation of pseudotracheidal tissue. 1. Sieve tubes; 2. Enucleate cells containing "X" bodies, one showing partial thickening of the cell wall; 3. Pseudotracheids; 4. Pseudotracheids containing "X" bodies; 5. Pseudoparenchyma.

3. The "sclerotic cells" of Kunkel (3) and Lyon (4), for which the writer suggests the more definite name of "pseudotracheid." These are lignified and pitted cells forming a tracheidal tissue which more or less surrounds the bundle, and groups of these cells may be interspersed among the phloem and parenchyma cells. They have no definite orientation, and are often branched. Their reticulately pitted or scalariform walls can be seen in transverse as well as in longitudinal section. They differ from the sclereides

of the polar caps of normal bundles in size, shape and pitting, and such sclereides are absent in gall tissue. This difference is especially noticeable in the leaf, where the sheath is normally composed of collenchyma with stratified and pitted walls. These pseudotracheids are arranged roughly parallel with the axis of the leaf, and true vessels are sometimes scattered through them.

4. A hypertrophied phloem, which, in leaf galls, may consist of over 100 sieve tubes and companion cells, and may form rays which project into the pseudotracheidal tissue and beyond it. An extreme case showed the phloem lying external to the sclerotic tissue in a stem bundle. The phloem of a normal macro-bundle in the leaf has from 16 to 32 sieve tubes, as determined from a number of counts.
5. The pseudoparenchymatous tissue, which is irregularly placed, but which lies in the main between the phloem proper and the sclerotic tissue, consists of equidiametrical cells with large and rapidly dividing nuclei. These are the cells which contain the Fiji or "X" bodies, known hitherto as *Northiella sacchari*, Lyon. These cells can be traced to give rise to the pseudotracheids and to sieve tubes, and radiate through these tissues more or less, without definite orientation. At times, a lone pseudoparenchyma cell will be observed in the pseudotracheidal tissue, with its large nucleus and unthickened cell wall (Fig. 1A, 5). These cells appear to form pseudotracheids by secreting a lignified cell wall, later lose their nuclei often show "X" bodies, and lastly lose their cell contents. Stages in this transformation are shown in Fig. 1, c and d. We thus find masses of phloem surrounded more or less completely by sclerotic tissue, and, at times, pseudotracheids surrounded by phloem.

In the stem, these gall bundles displace, and, at times disrupt the parenchyma of the stem, and their orientation, especially in the peripheral region, is very varied. They are characteristically asymmetrical, there being much more development of certain tissues on one side of the bundle than on the other.

The writer has not found, in any of the literature on this disease any mention of galls in the micro-bundles of the leaves, and they are likely to be overlooked. They are, however, characteristically present, and result in a hypertrophy of the phloem, the presence of a pseudoparenchyma consisting of a few cells, and the deformation and asymmetry of the xylem. Thus, the development of galls is not so localized as might be



imagined from a cursory examination, and hypertrophy occurs throughout the vascular tissue of the stem and leaf, which accounts for the very great deformation thereof in the later stages of the disease.

The chlorenchyma and epidermis on the abaxial side of the bundles may be disrupted in old galls.

Kunkel (3) gives the following description of the formation of the pseudotracheids:—"After a gall reaches a certain stage of maturity, a curious change takes place in the surrounding tissues. These tissues are derived from the cells that would normally produce the sclerenchymatous sheath, and, in some instances from portions of the phloem. Many of the cells of this tissue enlarge, and take on the staining reactions and appearance of tracheids. Their walls become thickened and lignified. Most of the thickening occurs as reticulate fibrous bands. The cells retain their shape, but become hard and woody."

In discussing the seat of the disease in the tissues, Kunkel states:—"The galls of Fiji disease always originate in the phloem and, although the disease affects other tissues to a certain extent it must be regarded as a phloem disease."

This is not in accordance with the present findings, for the pseudotracheidal tissues are as characteristic of the disease as the hypertrophied phloem, and so also are the undifferentiated cells. The writer considers that the cells containing the bodies, and the nucleate pseudoparenchyma are a persistent cambial meristem, which differentiates into a phloem and a false xylem, and that the seat of the disease is in this tissue, i.e., the disease is essentially meristematic, and causes a new growth comparable with that seen in carcinomatous sections of animals. The distribution of these cells with their large nuclei resembles that in carcinoma, as does the rapidity of their division. The occurrence of inclusion bodies cannot be paralleled in animal cancer, but is common in plant virus diseases. We cannot therefore push the analogy too far, but it is certainly worth noting.

In maintaining the theory of meristematic infection for Fiji disease, the findings of Arber (1) are of interest. She gives cases of the formation of a secondary metaxylem in monocotyledonous bundles in the Araceae. This takes place by means of a persistent cambial tissue, which is not characteristic of the monocotyledons as a group. The result is the formation of an amphivasal bundle as she figures. The general appearance of the bundle is similar to that of the Fiji gall, except that the distribution of the tissue is more uniform in the former. Phloem parenchyma is not normal in sugar cane, except in the growth ring region. The infective agent of Fiji disease appears to cause the persistence and proliferation of the cambium tissue,



or pseudocambium, for the cells are not quite typically cambiform. Their position is usually between the primary metaxylem and phloem in young galls, but later between the secondary metaxylem, and the phloem. They appear to give rise to phloem and xylem elements abnormally. This theory, derived from the anatomical evidence fits in well with the physiological evidence.

### III. Facts in Favour of Meristematic Infection.

(a) In Fiji diseased tissue the sieve tubes and companion cells are more numerous than in normal tissue, which suggests cambial activity.

(b) The pseudotracheids are, as serial sections of the galls show, produced by a metamorphosis of the pseudoparenchyma, which is certainly meristematic, as is observed by Kunkel.

(c) The sclerotic tissue is homologous with a secondary metaxylem. That this is so is confirmed by the study of the galls in the peripheral bundles of the stem, and the micro-bundles of the leaf. In the case of the former, the sclerenchyma sheath still exists in part, though it is less regular, and less developed than in normal tissue. The wood, instead of consisting of one to three definitely and symmetrically arranged vessels, is formed of a number of lignified elements which may divide the phloem into two parts. In this case, the pseudotracheids are continuous with the metaxylem. The pseudoparenchyma is associated with the phloem and pseudotracheidal tissue.

(d) In the earlier stages of the formation of the pseudotracheids, Northiella bodies are present in the partly thickened cells, but, later, the nucleus, cell contents and bodies disappear.

(e) Rays of sieve tubes frequently cut through the sclerotic sheath, and the phloem may lie outside this in the stem galls. There is no constant arrangement of the various tissues in a gall. The frequent occurrence of true vessels in the pseudotracheidal sheath strongly supports the assumption that this is a secondary xylem. In the peripheral stem bundles, tracheids may and do, at times, replace the vessels in healthy cane (Artschwager 2), and in Fiji diseased tissue, the peripheral bundles have, instead of one or two vessels or tracheids, a series of pseudotracheids as described above, arranged irregularly to the protoxylem, if this is present. Frequently, it is absent.

(f) The fact that this xylem is continuous with the pseudotracheids, and that pits occur between the two, strongly supports the theory, since pits are absent in the cells adjacent to normal vessels. In the very young galls, hypertrophy of the metaxylem is the first symptom, and later sclerotic patches are formed. The sclerotic cells, in leaf, and stem galls of the central type usually form a tissue surrounding the phloem more or less completely, but patches of this tissue may be isolated from the rest, and while the amphitracheidal type is commonest, there is considerable variation, as is the case with the majority of galls.

#### IV. Cytology of the Pseudoparenchyma.

In 1910, Lyon (4), published the first record of Fiji disease, in which he noted the presence of bodies in the gall parenchyma, and thought they were of a plasmodial nature. Subsequently Lyon (4), in collaboration with North, carried out some cytological studies on the disease, and later named the supposed parasite *Northiella sacchari*. He describes the bodies as being "usually vacuolate, and appearing to have the structure of dense protoplasm." He failed to find a definite nucleus, though, he asserts "a body resembling this was sometimes present." McWhorter (5) claimed some success in the cultivation *in vitro* of these bodies, but the writer was unable to repeat his results. It appears more probable that these inclusion bodies are homologous with those occurring in other plant virus diseases, and a study of the gall tissues strongly suggests that they are formed during the degeneration of the pseudoparenchyma cells into pseudotracheids.

From a study of a number of living and stained sections, the former mounted in isotonic sugar solution, it appears that the mononucleate pseudoparenchyma cell frequently becomes multinucleate, inclusion bodies appear, the nucleus disappears, as thickening of the cell wall occurs, and finally the bodies and cell contents disappear, and a pseudotracheid is formed (Fig. 1, B, C, and D). Further, from the fact that the bodies contain strongly chromatic material, and are much more strongly stained by nuclear stains than the nuclei themselves, the theory that they are composed of degenerating nuclear material becomes attractive.

#### V. Summary.

1. The vascular nature of the infection in Fiji disease is shown.
2. It is suggested that the seat of the disease is in a persistent cambium, and not in the phloem as previous authors have asserted.
3. The nature of the inclusion bodies is discussed.

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ART. XIX.—*On the Age of Certain Marine Deposits at Portarlington, Victoria, with a Proposed Subdivision of the Post-Tertiary Rocks of the Port Phillip Bay District.*

By J. T. JUTSON and ALAN COULSON.

[Read 10th December, 1936; issued separately 19th July, 1937.]

### Introduction.

Some fossiliferous beds are exposed in the sea-cliffs at two localities at Portarlington (Fig. 1). The more important section is about 1 mile to the east of the pier, close to a small projecting rock of coarse-grained ferruginous grit within 100 yards of the shore, which is marked on the military map of the district as Steele's Rock. The deposits may therefore be called the Steele's Rock beds. The second section commences just to the east of the pier, and the deposits may therefore be called the Pier beds. The fossils which have been found in these two sets of beds will, we think, throw a good deal of light on the Post-Tertiary geology of the Port Phillip Bay district, and incidentally of Victoria as a whole.

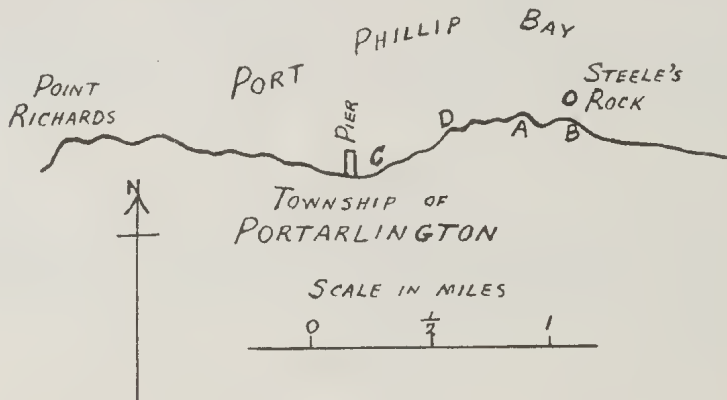


FIG. 1.—Locality plan. A—B. The Steele's Rock Section. C—D. The Pier Sections.

The Steele's Rock fossils were discovered by Mr. Andrew Blackburn, and we are indebted to him for directing our attention to their occurrence. We believe that they have only recently been exposed, owing to the extensive marine abrasion of the cliffs that is now taking place in the area mentioned. It is also possible that in the near future, by the same process, all trace of the deposits may be removed, if they happen, as appears likely, to be a remnant of a deposit formerly more widespread.

### The Steele's Rock Section.

This section extends westwards from about opposite Steele's Rock for a distance of approximately 300 yards, and eastwards from the same point for about 40 yards, making a total length of 340 yards. It forms the face of low vertical cliffs, varying little and not exceeding 11 feet in height above the present beach.

At the western end, for a distance of about 300 feet, Older Basalt (now decomposed practically to a clay) occurs up to a height of 8 feet above the beach, with a very uneven surface, owing to the rocks having been extensively eroded before the deposition of the overlying sediments, which, where seen to be resting directly on the basalt, have a maximum thickness of about 6 feet. Those which pass below sea-level are almost horizontal, with an exposed thickness of about 10 feet, but towards the eastern end they appear to dip to the east, and so increase in thickness. No estimate has, however, been made of the thickness of that portion, since the main interest centres in the western portion of the section (that is the portion, about 120 yards in length, to the west of the bathing box (Fig. 2)) where the sediments consist of mottled red, brown, and nearly white sandstones and grits, with which is associated a basal band of gravel (a conglomerate in places) usually not more than 3 inches thick, but occasionally reaching 10 inches, and traceable almost continuously for 100 yards. The pebbles of the gravels are, as a rule, well rounded, and consist of white quartz, slate, and sandstone with diameters up to 2 inches. The grits and sandstones

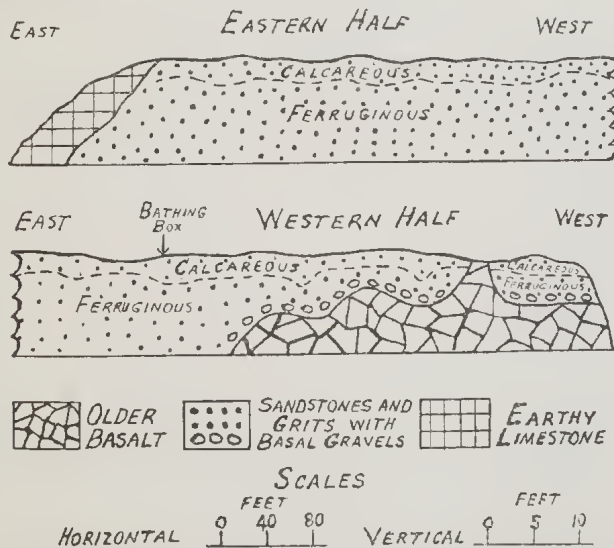


FIG. 2.—Section along the coastal cliffs at Steele's Rock, Portarlington. Some mottled clays which rest on the calcareous rocks in the eastern portion of the section, have been omitted.

are quartzose, cemented loosely together either by iron oxide or carbonate of lime, and consequently the deposits may be referred to as "the ferruginous beds" and the "calcareous beds" respectively. Where the ferruginous beds may be seen resting directly on the basalt, as in the western end of the section, they vary in thickness from 9 inches to about 5 feet.

The white and brown calcareous beds form a more compact rock than the ferruginous beds, although on weathering they develop a cavernous structure, and occur chiefly as a band at the surface of the section varying in thickness from 12 inches to 6 feet. The uppermost portions in places have been hardened by the further introduction of calcium carbonate in thin horizontal lines, with a resulting resemblance to the travertine bands in the dune limestone of Sorrento and elsewhere. Except for some broken shell fragments in the gravels, no fossils have been discovered in the ferruginous beds, but the calcareous beds are, in places, so full of fossils that the deposit may be described as a shelly limestone. The junction between the two sets of beds is uneven, and in places there are wedges up to 2 to 3 feet wide and deep of the calcareous beds in the upper surface of the ferruginous beds, forming "pockets" in the latter. In addition, there are, towards the western end, several small irregular patches, measuring in different directions from 6 to 18 inches, scattered through the ferruginous beds.

About a chain west of the bathing box (Fig. 2) the decomposed Older Basalt disappears owing to its deeper erosion. Proceeding eastwards, the sediments consequently increase in exposed thickness, and, as a whole, become more ferruginous and coarser-grained, with numerous thin bands of water-worn pebbles, mostly quartz, and with much current bedding. At the eastern end, they appear to dip to the east at about 30 degrees, under a yellow earthy limestone, which weathers into a nodular, uneven mass. The calcareous beds surmount the ferruginous beds practically all the way. The sandstones, grits, and earthy limestone are unfossiliferous so far as our observations go. In places, in the eastern portion of the section, there are above the calcareous beds, clayey gritty beds, much weathered, and from 2 to 3 feet thick. These have not been carefully examined, and no fossils were observed in them.

At each end of the whole section, there are small recent marine sediments which have been laid down with sea-level as at present, and which at the eastern end of the section rest on the denuded edges of the yellow limestone, and contain pebbles of that rock.

About 100 yards in a straight line west of the western end of the main section is a small, low, projecting point, composed of a deep red sandstone, which weathers out into rough blocks. No fossils have been found in these rocks.



In regard to the relations between the calcareous and ferruginous beds of the Steele's Rock section, the first impression is that they are quite distinct from each other, and are separated by an unconformity, the lower beds probably being of Kalimnan age, and the upper, Recent or late Pleistocene. Close observation, however, shows that the two rocks merge into each other without any physical break, that they are composed of exactly similar materials except as regards their respective cements, and that even the distinctive colours of the beds merge into each other almost imperceptibly. This conclusion was arrived at from a study of the general line of contact of the two groups, and it is placed, in our opinion, beyond doubt (1) by the occurrence in the western portion of the already noted small calcareous fossiliferous patches in the heart of the ferruginous beds, the former having direct continuity on all sides with the latter without being mere cavity filling; and (2) by the occurrence, at one or two places in the western portion of the section, of scattered recent shells more or less from top to bottom of the sediments.

The eastern portion of the section appears very strikingly to contradict the conclusion that the two beds really form a homogeneous whole, but careful examination shows that the apparent unconformity does not exist, the explanation being that the carbonate of lime is a surface deposit, probably derived from the solution of the shells which originally occurred in the lower beds. Similarly, we find throughout the whole section that the carbonate of lime is the preserver of the fossils.

### **The Pier Sections.**

The relevant sections commence within 100 yards east of the pier, and extend for about half a mile eastwards as sea-cliffs. The greatest exposed thickness of the sediments is not less than 25 feet, but there is much variation in this respect. They rest on the irregularly eroded surface of the Older Basalt, and consist usually of medium and occasionally coarse-grained quartzose sands, with a coating of light-brown iron oxide, not as a rule, however, in sufficient quantity to cement the sands into a firm rock. Gravels, basal and otherwise, composed of well rounded pebbles, up to 3 inches in diameter, of quartz, slate, and sandstone in thin bands are associated with these sands. At one place, the typical light-brown sediments passed upwards without any physical break into a white calcareous-looking rock, generally similar to that of the Steele's Rock area. No fossils were found in this white patch, but the ferruginous beds, although generally unfossiliferous, yielded in three separate places small marine molluscs of species now living.

We originally had some doubt as to whether the shells had not been carried to their present positions by human agency, but the number of outcrops, and their mode of occurrence, have

satisfied us beyond reasonable doubt that they are actually imbedded in the rocks, although mostly found in small masses projecting 2 or 3 feet from the main body of the cliffs above. The shell bands are usually not more than an inch thick, and their traced length usually does not in any individual outcrop exceed 8 feet. At least seven distinct outcrops have been noted, and four of these occur in a length of between 30 and 40 yards in the most westerly portion of the section close to the pier. The height of the outcrops above the beach varies from about 15 to 25 feet. There may consequently be more than one bed of shells, but this point is difficult to determine.

### Fossil Contents.

Fossils collected from the Steele's Rock section have been kindly examined for us by Mr. F. Chapman, A.L.S., F.G.S., and his determinations are as follows--

#### PELECYPODA

- Arca (Barbatia) fasciata* Reeve
- Mytilus planulatus* Lam.
- Brachyodontes rostratus* (Dunker)
- Chlamys bifrons* (Lam.)
- (?) *Diplodonta* sp.
- Cardium rackettii* Don.
- Eumarcia nitida* (Q. and G.)
- Pseudarcopagia victoriae* (Gatl. and Gabr.)

#### GASTEROPODA

- Patelloida conoidea* (Q. and G.)
- Monodonta ? constricta* Lam.
- Cantharidella cf. liberiana* (Crosse)
- Polinices conicus* (Lam.)
- Bittium granarium* (Kiener)
- Diala lauta* Adams
- Pyrazus diemenensis* (Q. and G.)
- Nassarius victorianus* (Iredale)
- Neothais succincta* (Martyn)
- Conus anemone* Lam.
- Bullaria botanica* Hedley

All the specimens determined are of species now living.

### Age of the Beds.

So far as examined, there are no extinct species, so that the rocks are apparently younger than the Werrikooian (the typical basal bed of which contains about 5 per cent. of living species in a molluscan fauna of nearly 200 species) which Singleton (1935, pp. 132, 134) regards as of Upper Pliocene age. The Port-arlington beds must therefore be regarded as not older than Pleistocene, and for reasons stated below, we place them tentatively as Lower Pleistocene.

**Correlation with other Deposits of Tertiary or Post-Tertiary Age of the Port Phillip Bay District.**

Rocks, generally similar lithologically to the ferruginous portions of the Steele's Rock and Pier sections, occur as a fringe around the Bellarine Peninsula, as, e.g., at Clifton Springs, Portarlington (west of the pier), St. Leonards, Ocean Grove, Lake Connemare, and over extensive areas of the interior of the peninsula. These deposits have not, so far, yielded any fossils, but they overlies, in places, fossiliferous Tertiary deposits of Kalimnan and of greater age. Most of the upper beds above referred to were regarded by Hall and Pritchard (1893, pp. 2, 9, 19) as of probably Upper Tertiary age. These upper beds have apparently never been carefully examined, so that, at present, it cannot be stated whether or not they are conformable to the lower proved fossiliferous ones; nor, in the absence of fossils, can they be correlated, except provisionally, with the beds described in this paper.

Beds, lithologically similar to the upper deposits just referred to of the Bellarine Peninsula, and not yet proved to be fossiliferous, occur on the eastern side of Port Phillip Bay, as at Mornington, Frankston, Beaumaris, and Brighton; and also inland, as at Green Gully (Keilor), Northcote, Preston, and Brunswick. They also, in places, rest on fossiliferous Tertiary deposits of Kalimnan and of greater age, but in other places they lie directly on the Silurian. These deposits, owing to their apparent conformity with the underlying fossiliferous beds where the latter occur, were, like those of the Bellarine Peninsula, generally regarded as Upper Tertiary. (Hall and Pritchard 1897, p. 223) as to the Brighton and Beaumaris beds; (*ibid.*, p. 213) and Crespin (1925, p. 103) as to the Green Gully beds; and Kitson (1900) and Chapman (1914 and 1921) as to the Frankston beds). It is, however, of considerable interest to note that T. S. Hart (1893, p. 156) many years ago recorded his opinion that in the Brighton district the fossiliferous lower rocks were separated from the upper, apparently unfossiliferous ones, by a distinct unconformity. Hall and Pritchard (1897, pp. 190 and 202) later examined these beds, and whilst they agreed that unconformities existed, they considered them to be small local irregularities without indicating any difference in age of the two sets of beds.

Beds of much the same type outcrop at Studley Park, from which a fossil has been obtained, which Chapman (1923) regards as being probably indicative of Kalimnan age; but more evidence is desirable before coming to a definite conclusion on this point, and therefore these Studley Park beds are not here taken into consideration. Should, however, the Kalimnan age of these beds be confirmed, there is the possibility of overlying unfossiliferous beds having been removed by erosion.

Further examples of apparently unfossiliferous sediments resting on fossiliferous Tertiary rocks are indicated by the Newport Bore (Hall and Pritchard, 1897, p. 215), and by the Altona Bore (Hall and Pritchard, 1897, p. 218; and Thiele and Grant, 1901, p. 145).

All these uppermost apparently unfossiliferous beds are for the present grouped together by us, and their tentative classification would be either Werrikooian or Lower Pleistocene. As between these two ages, we suggest the latter, since we place the Portarlington beds in the Lower Pleistocene, and there is a general resemblance to the Portarlington beds in lithology and mode of occurrence.

The Royal Park beds are all fossiliferous, although scantily so in their upper portions, and are regarded by various authorities as being not younger than Kalimnan, so that that area need not be further considered here, except to point out that it is possible that there were originally overlying non-fossiliferous sediments which have been removed by erosion.

From an exhaustive examination of the records of the deep bore at Sorrento, Chapman (1928, p. 180) regarded the limiting depths of the Pleistocene as between 112 feet and 489 feet in the bore. He states that the series contains mollusca, which are all of recent species, that the basal bed (489 feet) exactly resembles estuarine beds found at slight depths at the mouth of most Victorian rivers, and that the dune rock found within the limits mentioned is consolidated exactly like the old Sorrento limestone, which contains extinct marsupials. Chapman (*loc. cit.*), whilst considering that the bore records afford no tangible palaeontological evidence on which to work in regard to the delimitation of the Werrikooian division, yet, in lieu of better evidence, takes the depth from 490 feet down to 520 feet as probably comprised within the Werrikooian, but he points out that in the series allocated provisionally to the Werrikooian, at the depths stated above, the deposits show a good deal of relationship to the Pleistocene.

Any correlation of the Portarlington beds with the deposits of the Sorrento bore must, we think, be restricted to the deposits between 112 feet and 520 feet. The Dune Limestone occurs between 112 feet and 489 feet, and, although it cannot be said that the deposits (or at least those at a moderate depth) are contemporaneous with the Dune Limestone outcropping at Sorrento, Queenscliff, Point Lonsdale, and Barwon Heads, yet if a conclusion, however tentative, must be drawn, the affinities of the bore beds between 112 feet and 489 feet certainly appear to be nearer to the surface Dune Limestone than to the Portarlington beds, which we regard as considerably older than the surface Dune Limestone.



From the slender evidence available, there appears to be a closer relationship between the Portarlington beds and those of the Sorrento bore between 490 feet and 520 feet, which consist of an ochreous sandy clay and consolidated microzoic sandstone (Chapman, 1928, p. 180); and Chapman, as already mentioned, is doubtful whether they should be placed in the Werrikooian or the Pleistocene. For the reasons stated, we incline to the latter age.

The fossiliferous beds discovered by Mulder (1901) beneath the Newer Basalt at the Moorabool railway viaduct (which are about 20 miles to the west of the Portarlington beds, and which have an elevation above sea-level of probably about 150 feet) were regarded by Tate as of Older Pleistocene age, although Mulder, from their general resemblance to the marine beds of south-western Victoria, which Dennant had classified as Upper Pliocene, placed them in that division.

The following are the fossils recorded by Mulder, with the nomenclature (not determinations) brought up to date, for which we are indebted to Mr. Chapman:—

- Neothais succincta* (Martyn)
- Perconella tasmaniensis* (Adams and Angas)
- Nassarius lyrella* (Beck)
- Nassarius victorianus* (Iredale)
- Pyrazus diemenensis* (Quoy and Gaimard)
- Turritella clathrata* (Kiener)
- Polinices aulucoglossa* P. and V.
- Bombicium melanostoma* (Cmelin), var. *plana* (Q. and G.)
- Ostrea virescens* Angas
- Chlamys antiaustralis* (Tate)
- Mytilus planulatus* Lam.
- Bassina paucilamellata* (Dunker)
- Pholas australasiae* Sow.
- Teredo* or *Nausitoria* sp.
- Magellania flavescens* Lam.

Mulder's list also includes *Ostrea mordax* Gould, *Mytilus magellanicus* Lam.(?), *Corbula scaphoides* Hinds, and *Balanus* sp., but Mr. Chapman queries the identity of *Ostrea mordax* Gould and *Mytilus magellanicus* Lam., and also points out that *Corbula scaphoides* Hinds, if typical, belongs to the genus *Aloidis*, but specimens require revision. He has also referred us to the record by Dennant and Kitson (1903, p. 142) from the same locality of *Cancellaria granosa* (Sow.). He concludes that all the forms seem to belong to living species.

Singleton (1935, p. 132) places the Werrikooian in the Upper Pliocene, the type beds being those of south-western Victoria, already referred to. He states (p. 133) that the Moorabool viaduct beds are perhaps referable to the Werrikooian, as also the sandy clays and sandstone at about 500 feet in the Sorrento



bore, but he considers it difficult to draw a boundary between Tertiary and post-Tertiary sedimentation, and that some of the strata referred to the Werrikooian may be Pleistocene. We gather, however, from Mr. Singleton that he now tends to regard the Moorabool beds as belonging to the Werrikooian rather than to the Pleistocene; but the age is still apparently in doubt. In any event, by reason of the facts that lithologically there is considerable similarity between the calcareous portions of the Steele's Rock section and the Moorabool beds, and that, as indicated below, we regard the Portarlington beds as older than the Newer Basalt, we consider that there is a close relationship between the Portarlington and Moorabool beds, but that the latter are slightly older than the former, whether the Moorabool beds are ultimately found to be Werrikooian or Pleistocene. At present we incline towards placing both deposits in the Pleistocene, notwithstanding the difference in altitude above sea-level of their respective outcrops, since, in a distance of 20 miles, that difference can no doubt be explained by the occurrence of an irregular erosion surface at the time of the deposition of the beds, or by unequal uplift, warping, or faulting, or by the combined action of these two forces. The Portarlington beds, and provisionally also the Moorabool beds, are placed by us in the Lower Pleistocene with the difference of age indicated above.

The Portarlington deposits we consider to be older than, and separated by, a pronounced period of erosion from the Newer Basalt for the following reasons:—The sediments are apparently either of the same age or closely related to the similar deposits of the Bellarine Peninsula, of the eastern shore of Port Phillip Bay, and of the country around Melbourne. The basalt does not reach Portarlington or the eastern shore of Port Phillip Bay, but it occurs in the valley of the Yarra and some of the tributaries of the latter; always, however, as flows after the dissection by stream action of the deposits, which for the purpose of this discussion are assumed to be of the Portarlington type. Nowhere in the vicinity of Port Phillip Bay or elsewhere, so far as we are aware, do sediments of the type mentioned rest on the basalt; and the Moorabool beds are below the basalt. The greater part of the Newer Basalt series is regarded by Singleton (1935, p. 134) as Pleistocene. Owing to the probable periods of erosion between the deposition of the Portarlington rocks and the effusion of the Newer Basalt, and between the latter and the Dune Limestone, the basalts are assigned to the Middle Pleistocene.

The Dune Limestone of the Sorrento Peninsula, Queenscliff, Point Lonsdale, and Barwon Heads we consider to be younger than the Newer Basalt, and, consequently, considerably younger than the Portarlington and Moorabool beds. At Barwon Heads the limestone rests upon the basalt, and nowhere in the wide area

of the Port Phillip Bay district, so far as known to us, are sediments of the Portarlington type or basalt of the Newer Basalt series found resting on or interbedded with the Dune Limestone. The latter we place partly in the Pleistocene, owing to the finding of the remains of an extinct kangaroo in that rock (J. W. Gregory, 1901, who considered the lower part of the limestone to be late Pliocene or Lower Pleistocene), but the limestone probably passes into Holocene. (See Singleton, 1935, p. 133.) There has been deep dissection of the Newer Basalt of the Port Phillip area, and it appears most probable that the Dune Limestone was not deposited until that dissection had advanced to a considerable stage, although there is no direct evidence as to that. The Dune Limestone in its lower portions is therefore assigned by us to the Upper Pleistocene, and in its upper portions to the Holocene, although we are at present unable to indicate any line of demarcation between the two divisions.

The thin marine beds fringing the coast of Port Phillip Bay, e.g., at the Yarra mouth, Altona, Little River, Point Henry, Point Lonsdale, Roscbud, Carrum, and Elwood, from their mode of occurrence and fossil contents, are regarded by us as all approximately of the same age. The same features suggest that they are younger than both the Newer Basalt and the Dune Limestone, and this inference is confirmed at Altona, where they rest upon the Newer Basalt, and in the Point Lonsdale district, where they lie upon the eroded surface of the Dune Limestone. The occurrence of the latter rock at considerable depths in the Sorrento bore (see Chapman, 1928, pp. 7 to 10 and 180), also points to the same conclusion. We therefore place these marine deposits in the Holocene. Singleton (1935, p. 134) thinks that the Altona beds are probably not as old as Pleistocene.

The limited deposits of freshwater limestone at Lara and Limeburners' Point, Corio Bay, Geelong, rest upon the Newer Basalt, but their relation to the Dune Limestone is not clear. Pritchard (1895, p. 40) appears to incline to a Pleistocene age for these freshwater limestones rather than Newer Pliocene as suggested by McCoy. In view of the stratigraphical position assigned by us to the Newer Basalt, we place them in the Pleistocene, but whether they are late Middle Pleistocene or Upper Pleistocene cannot at present be stated. The amount of dissection by stream action that they have undergone at Lara makes us, however, incline to the former, and therefore in the table below, they are placed in that series.

If our conclusions are correct as to the succession of the beds, then, since the Newer Basalt is not represented in the Sorrento bore records, there may be an unconformity or disconformity in the Pleistocene rocks recorded by that bore, which may indicate pauses in the downward movement of the rocks and also erosion during the whole or portions of those pauses.

In view of the possibility suggested above that some of the sediments, hitherto found to be unfossiliferous, may be of the same age as the Portarlington beds, a protracted search for fossils in the sediments mentioned is required, and evidently the most likely places are the calcareous portions (if any), since it is in those portions of the Portarlington beds that most of the fossils occurring there have been found. The fossiliferous rocks of the Moorabool viaduct section, those of Kalimnan age at Lake Connewarre (Coulson, 1935, p. 3), those at Frankston of Janjukian age (Chapman, 1921, p. 11), and those of the Glenelg River of Werrikooian age (Singleton, 1935, p. 132), are or were (the Frankston beds having been changed into ironstones) calcareous.

It is of interest to note that, in the sections at Portarlington dealt with in this paper, the Balcombian, Janjukian, Kalimnan, and Werrikooian are missing.

### **Subdivision of the Post-Tertiary Rocks of the Port Phillip Bay District.**

We now tabulate the results of the preceding remarks as a basis for further observation and discussion, and suggest the following subdivisions:—

1. *Lower Pleistocene*.—(i) The marine beds of the Steele's Rock and Pier sections, Portarlington. (ii) The ochreous sandy clays between 490 feet and 520 feet of the Sorrento Bore. (iii)(?) The Moorabool viaduct upper beds, these being somewhat older than the Portarlington beds. (iv) Probably some of the sediments, hitherto found to be unfossiliferous, overlying the fossiliferous Tertiary rocks of the Bellarine Peninsula, the eastern side of Port Phillip Bay, and generally around Melbourne.

Uplift and deep erosion, with the formation of pre-Newer Basalt valleys.

2. *Middle Pleistocene*.—Period of extrusion of the greater portion of the Newer Basalt series, followed by the deposition of the freshwater limestones of Lara and Limeburners' Point, Geelong.

Mostly subaerial. Probably a comparatively short period. Deep erosion, with formation of post-Newer Basalt valleys.

3. *Upper Pleistocene*.—Lower portions of the Dune Limestone of the Sorrento Peninsula, Queenscliff, Point Lonsdale, and Barwon Heads. Characterized by the presence of an extinct kangaroo (Gregory, 1901).

4. *Holocene*.—(i) Upper portions of the Dune Limestone. No line of demarcation has yet been ascertained between the upper and lower portions of this limestone.

Erosion (of the Dune Limestone mainly by marine abrasion) followed by (ii) The marine beds fringing the coast of Port Phillip Bay at the localities indicated above; and the latest alluvium, sand dunes, and swamp deposits.

In conclusion, we desire to acknowledge our indebtedness to Mr. F. Chapman, A.L.S., F.G.S., and Mr. F. A. Singleton, M.Sc., for their criticism of this paper.

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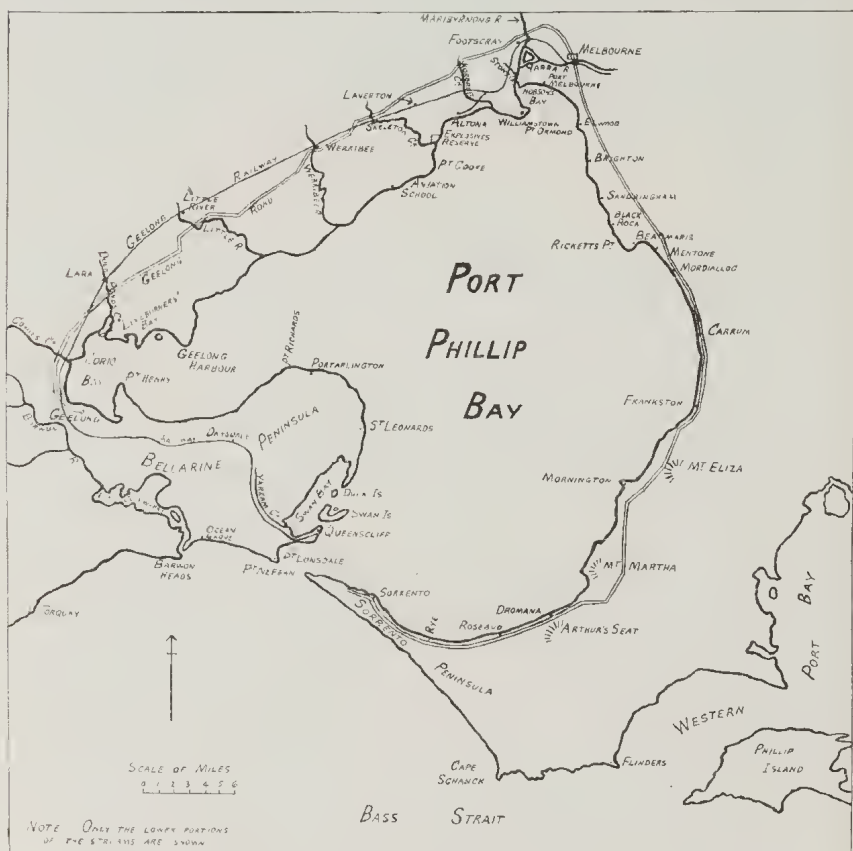


FIG. 3. Port Phillip Bay, showing most of the places referred to in the text.



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**LADY JULIA PERCY ISLAND.**

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REPORTS OF THE EXPEDITION OF THE  
McCOY SOCIETY FOR FIELD INVESTIGATION  
AND RESEARCH.

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*1. General Introduction.*

By PROFESSOR F. WOOD JONES.

The McCoy Society for Field Investigation and Research came into existence in August, 1935. Its purpose is expressed in its title. Its beginnings were humble but its aims ambitious. Its success has been assured by the industry of its workers in the field and by the very gratifying financial help that has been so readily forthcoming from those who have seen in the birth of this Society the initiation of a movement that is destined, if continued upon the right lines, to accomplish work that is of the utmost importance in Australia. The study of the ecology of definite Australian environments is one that has utilitarian, as well as scientific, value. This aspect has been appreciated by many friends of the Society and it is owing to their generosity that the work, so far accomplished, has been made possible.

For the first season's work Lady Julia Percy Island was chosen as being a small, self-contained, and readily accessible sample of the Australian environment. The island was one upon which, with the Society's somewhat slender funds, a camp could be maintained for a period of some two months. But although Lady Julia Percy Island is of limited area and of not very difficult access, it proved to be by no means a typical sample of the insular environment of the southern shores of Australia. By a strange chance the Society had selected as its first field for investigation an area possibly unique among the offshore islands of our South coast. Lady Julia Percy Island proved to be a pure volcanic mass uprisen in the sea, and not, as are the general run of offshore islands of the South Coast of Australia, a part of the old continental mass sundered from the mainland. Herein lay the interest of the first season's work. For the geologists there was the problem of an isolated volcanic mass that has almost certainly never been connected with the mainland of Australia. For the agriculturalist the problem of a purely volcanic soil with its attendant peculiarities of chemical composition and soil bacteria. For the biologists there were the problems of the arrival, and survival of plant and animal life in a peculiar environment to which each must come as a waif by some chance or other. And finally there is the question of weaving all the problems into a whole fabric so that we may come nearer to understanding the reactions of all the factors of an environment, organic and inorganic, the one towards the other.

A definite contribution towards this understanding was made by the members of the McCoy Society in its camp on Lady Julia Percy Island. But, although the generosity of many friends had made the work on the island possible, little would have been

gained if this work had been destined to remain chronicled only in the note books of the various members of the Society. It is due entirely to the vision and generosity of Messrs. G. and A. M. Nicholas that publication of our initial efforts has been made possible.

The papers included in the present publication are to be regarded merely as a first contribution. Several major questions, of vital importance to Australia, remain for discussion. The problem of the introduced rabbits and the question of their control may well be put to the test on this island. The question of the influence of a colony of seals upon the fishing industry is capable of some solution, if the data collected by the Society are placed upon record. In the papers that are here published there is no more than a record of the work of various members of the Society. Their findings are permanent records of the state of the island ecology as it was at the time of their visit. The McCoy Society has established one landmark—it has recorded, as completely as possible, the state of the balance of nature in Lady Julia Percy Island in the summer of 1935-1936. This is only a beginning—a beginning made possible by individual enterprise and by individual generosity. It would be encouraging if it might be assumed that in the not far distant future the Society should not seek its funds from private individuals, generous though they have been, but that it should be relieved of financial worries by definite grants made from research funds administered by some corporate body.

## 2. *Historical Introduction.*

By D. J. MAHONY, M.Sc.

Early in the year 1800 Lieutenant James Grant sailed from England for Sydney in command of H.M. armed surveying vessel *Lady Nelson*, 60 tons. At Cape Town he received orders to proceed through the Strait lately discovered by Bass separating Tasmania from the mainland, and to examine the coasts on both sides of this passage. Grant in his unpublished journal made the following note (quoted from *The Portland Bay Settlement* by Noel F. Learmonth):—

“Dec. 6, p.m. At three made a considerably large island, high and inaccessible on all sides. We had an opportunity of seeing, apparently, a good soil with grass on it, but no trees. This I named Lady Julian’s Island in honour of Lady Julian Peirce.”

Grant’s chart of the north and west parts of Bass Strait gives the name as Lady Julia Percy’s Island. Ida Lee, in *The Log-books of the Lady Nelson*, reproduces Governor King’s “eye sketch” made in 1800 from Grant’s report, and here the name is Lady Juliana’s Island. Flinders’ chart of Terra Australis, 1802, shows “Lady Jul. Percy’s I., a cliffy, flat-topped isle.”

Nicholas Baudin sighted the island on 1st April, 1802, and described it as “entièrement dépourvue d’arbres et semble n’être couverte que par une espèce de bruyère très peu élevée” treeless and seemingly clothed only with low-growing broom (or heath). Sixty years later, A. C. Allan, the surveyor, wrote in an official letter that “the whole island is covered with low, thick scrub, rushes and creepers, and the [trigonometrical] station being situated on the opposite side from the landing, great delay was experienced in moving up the observatory and instruments to the station.” At the present time no trace of scrub remains.

Within a few years of the discovery of Bass Strait, sealers had visited every rock and island in it, and as far west as Spencer Gulf. Seals were ruthlessly slaughtered and almost exterminated; as early as 1807, Surgeon Luttrell writing from Sydney, said that sealing was greatly on the decline as nearly all the seals on the islands of the southern coast had been destroyed or had abandoned the islands in consequence of depredations by sealers. Sealers apparently made no permanent settlement on Lady Julia Percy Island, but two were buried there, one in 1822 and the other in 1828.

On two occasions the island was used as a site for trigonometrical stations during extensive surveys. In 1840 A. J. Tyers used a station on the eastern point of the island during his survey of the coast between Melbourne and the Glenelg River. While the geodetic survey of Victoria was in progress, A. C. Allan used



a trigonometrical station near the southern end of the island in 1863 and built a cairn 8 feet high over the marked stone which indicates the spot. Neither of these surveyors mapped the island.

Prior to 1876 a deposit of guano in a cave at Sealers Cove was exploited, but little was obtained and work was soon abandoned. Between 1879 and 1908 various applicants were granted grazing licences. Pig breeding was tried about 1884, but was not payable and the pigs were allowed to run wild; about 50 years ago they were rounded up by local fishermen and shipped to Melbourne.

Mr. E. C. Griffiths, formerly of Port Fairy, has supplied some interesting information. His father, Mr. J. Griffiths, released a pair of ordinary grey rabbits and some guinea fowl on the island in 1868. In 1886 the Government decided to establish an emergency station for castaways, and Mr. Griffiths and his father carried out the work in that year, spending about three weeks on the island. At that time there was a patch of dense tea-tree scrub near the southern end of the island and the rest was covered with bracken, grass and rushes. Pigs and a horse taken to the island by former occupants had run wild. Rabbits were abundant and some guinea fowl had survived. Seals, penguins and quail were there in great numbers, but no mutton birds. The wooden tramline that had been used to take guano from Sealers Cove to the landing place had fallen into decay and all the guano had been removed.

### 3. *Topography and Physiography.*

By IRENE E. DEWHURST.

As the island is entirely volcanic in origin, its surface physiography is controlled by the later lava flows. The nearly horizontal disposition of these flows has determined the low, flat-topped nature of the island, the heights ranging from 105 feet at the lowest (northern) end to 152 feet at the highest (southern) end. No definite drainage system has developed. Depressions in the surface, such as the area known as "The Swamp," may be due to the collapse of lava tunnels in the underlying basalts, while the land to the south is relatively higher owing to the proximity of the centre of eruption, where a greater accumulation of volcanic material in the form of scoria and tuff occurred. Apart from a ridge half a chain south of the camp, and that east of Cairn 2, formed by the edge of the sixth and last lava flow, which only partially covered the previous one, there is no land form to break the monotonous flat top of the island.

#### **Coastal features.**

The coast line, in general, is extremely rugged, including many small bays and projecting headlands, and the island is surrounded by nearly vertical cliffs which are due directly to undermining of the rock faces by wave attack, and collapse of the upper sections.

With the exception of the south-western portion of the island in the vicinity of Horseshoe Bay, where there is solid basalt, the rock at water level is the boulder tuff, which is readily eroded.

The caves in general extend inland, normal to the cliff face. In bays, the force of the waves is concentrated in the corners, where caves are formed, as shown by Seal Cave, near McCoy Platform, and the caves in Horseshoe Bay. The Fern Cave and Guano Cave in Seal Bay, which are now 15 feet above sea level, may represent the remnants of normal caves developed before the formation of Seal Bay, the later accumulation of shingle, and, in the case of Fern Cave, landslip material, blocking the lower part of their entrances and thus rendering them inaccessible to the waves.

Where the junction of the boulder tuff with the solid basalt flows above is less than 40 feet above sea level, the cliff profiles are modified by the development of storm wave nips at this junction. Examples of these are found in the cliff profiles of all the headlands south of Cape Frederie and at Dinghy Cove and Sphinx Head. At the west end of the island, where the cliffs consist of solid basalt, however, no nip is developed.

Several scoriaeous reefs occur at the heads of the bays, Square Reef and Delta Reef being the largest. These are associated with the general processes of marine erosion, and are remnants

of typical shore platforms. Square Reef is approximately 20 square chains in area and rises from 5 to 6 feet above low water level.

McCoy Platform, at the north head of Seal Bay, is an example of a wave-cut platform. This comprises a ledge, 25 to 30 feet in height, of relatively harder rock which has resisted marine attack during the denudation of the upper portions of the cliff by storm waves (see Figs. 1 and 2). With regard to these

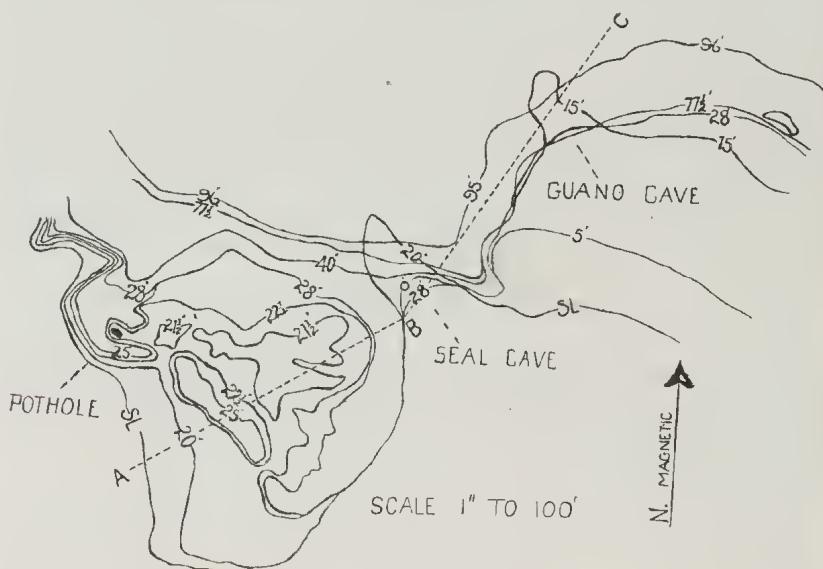


Fig. 1.—A detailed contour map of McCoy Platform and a westerly portion of Seal Bay, locating the pothole (in black) and Seal and Guano Caves (from survey by L. W. Stach).

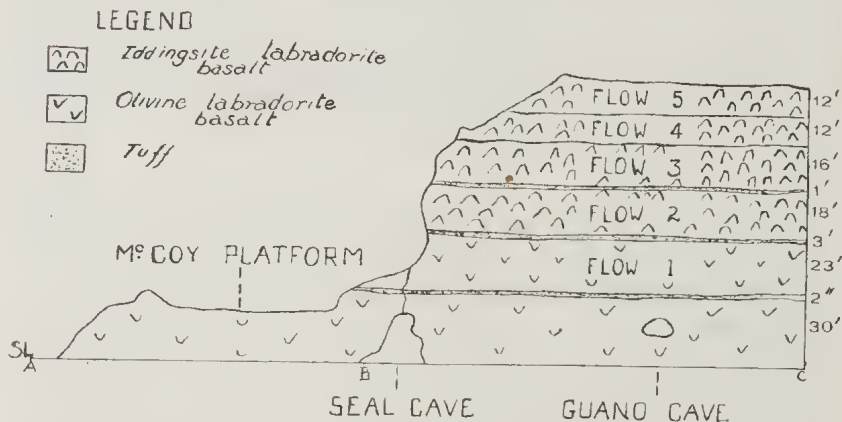


Fig. 2.—Section through McCoy Platform, Seal and Guano Caves. Types and thicknesses of the various volcanic phases are indicated.

waves, it may be stated that the effect of tides on the waters in the vicinity of the island is negligible, being entirely subsidiary to the banking up of water on the windward side of the island by the wind.

The centre of eruption of the later volcanic series now forms a physiographic feature in the form of a volcanic neck of dense columnar basalt constituting the headland, Pinnacle Point.

Talus fans are to be found at Landslip Point and in Dinghy Cove, where they rest at an angle of 27 to 30 deg. against almost vertical cliffs. These are products of the normal atmospheric weathering of the cliffs.

Shingle beaches, formed by wave attack on the material of the talus fans, are found at the head of some bays, as illustrated by the seal beaches in the vicinity of Landslip Point and the beaches in Dinghy Cove and Seal Bay. Drift materials from the mainland and from the sea floor between the island and the mainland also collect here as very much rounded, and frequently bun-shaped pebbles of rock types not found on the island.

*4. General Geology.*

By LEO. W. STACH, B.Sc.

The island is entirely composed of volcanic rocks, and appears to have been developed during two successive periods of vulcanicity. The earlier volcanic outburst resulted in the development of the so-called boulder tuff together with flow 1, which are seen in section in the cliffs of the northern half of the island (Plate XIX., Fig. 1). The boulder tuff dips southward, its top being 60 feet above sea level at Cape Frederic, and 30 feet above sea level at Sphinx Head.

It consists of large ellipsoidal lava boulders up to 2 feet in their shorter diameter, and often showing concentric flow ridges, embedded in a matrix of fine yellow tuff and larger scoriaceous fragments averaging about 2 inches in diameter (Plate XIX., Fig. 2). Passing along the west coast from Dinghy Cove, there is a gradual diminution in the proportion of matrix until in the vicinity of McCoy Platform the boulder tuff is replaced by ropy lavas (Plate XX., Fig. 3), while further west, in Seal Bay, the ropy lava is replaced by denser basalt.

Succeeding the boulder tuff is a flow of basalt varying from 6 feet in thickness at Dinghy Cove to 23 feet at McCoy Platform. Petrological examination has shown both the boulder tuff and the succeeding flow (Flow 1) to be olivine-labradorite-basalt. At Pinnacle Point this volcanic series ends abruptly at the vent which initiated the later period of vulcanicity. No evidence of a vent which could have given rise to the earlier series was observed on the island.

Along the west coast, overlying flow 1, is a tuff varying in thickness from 2-6 feet until, on both sides of the neck of Pinnacle Point, it passes into a tuff cone about 30-40 feet in height, where it forms the lip of the crater from which the later flows were extruded (Plate XX., Fig. 4). The proportion of scoriaceous fragments in the tuff increases with proximity to the cone. At Landslip Point no scoriaceous fragments occur, but at McCoy Platform, there is a large proportion of fragments 2 or 3 inches in diameter.

At the head of Horseshoe Bay large ejected lava blocks, several feet long, are seen in the tuffs, which, in the cone itself, consist of thin layers varying in their resistance to weathering, indicating numerous short explosive outbursts. The remainder of the cone must have extended to the west of Pinnacle Point, and it appears probable that the tuff cone was breached only on its eastern side, thus giving rise to the later flows (2-6), while the unbreached (western) side of the cone has disappeared as a result of marine attack.

Overlying the tuff is a succession of lava flows (Flows 2-6), which petrological examination has shown to consist of iddingsite-labradorite-basalts. In the cliffs of the western coast from Cape



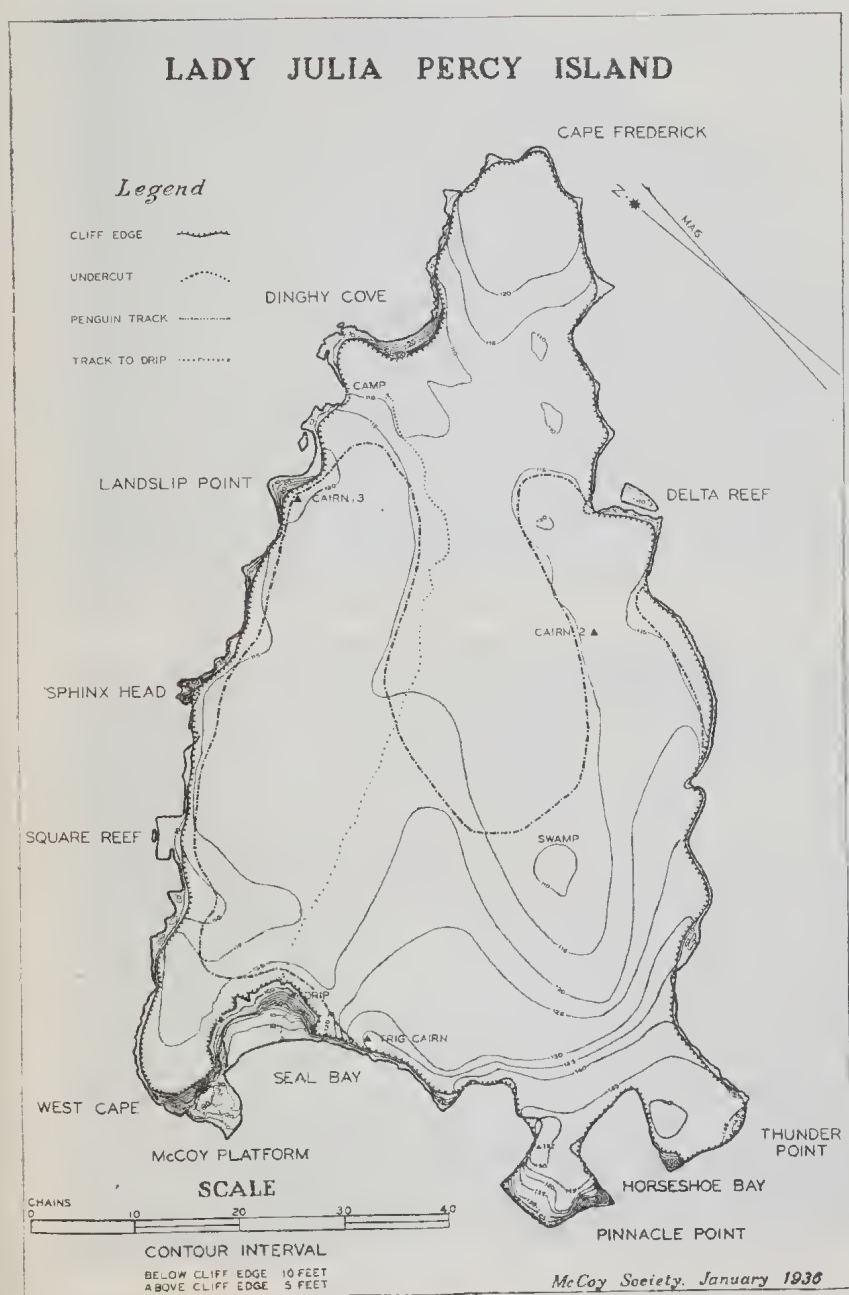


Fig. 1.—Map of Lady Julia Percy Island (from survey by L. W. Stach), showing boundary of the latest iddingsite-labradorite-basalt flow (Flow 6), indicated by an alternate dot-dash line.

Frederic to Seal Bay only four of these flows are seen in section, but in the headland south of Delta Reef, and in the cliff sections about 20 chains south of Delta Reef, a fifth iddingsite-labradorite-basalt is present. These flows vary in thickness from about 8-18 feet. In section, they are demarcated by the distribution of the gas cavities, the base of each flow being usually moderately vesicular for about 6 inches, while the upper 2 feet becomes increasingly vesicular to the surface. The central portions of the flows are very dense, but they are traversed by occasional long, slender, vertical, cylindrical pipes of vesicles.

The last flow (Flow 6) only partially covers the preceding flows, and extends from the vicinity of the vent in two tongues. One tongue passed to the Trig. Cairn and then south almost to the Camp, but does not extend to the cliff edge; the other followed the east coast as far as Delta Reef, but failed to reach the cliff edge along the depression below the 115 feet contour east of Cairn 2 (Fig. 1).

The actual pinnacle which forms the western headland of Horseshoe Bay consists of very dense resistant columnar basalt at its base and represents portion of the throat of the vent which initiated the later period of vulcanicity (Plate XX., Fig. 4).

Between some of the iddingsite-labradorite-basalt flows, thin bands of tuff occur, indicating short explosive outbursts between periods of effusive vulcanicity.

The island rises abruptly from depths of 20-25 fathoms at the southern end, while at the northern end, a long reef at a depth of 9 fathoms continues the foundation of the island, and then passes down to depths of 20-25 fathoms. The northern reef appears to be connected with the earlier period of vulcanicity. The isolation of the island from the mainland by deep water suggests that the island has developed quite independently as a result of submarine volcanic activity, and the presence of the vent producing the later flows supports this view. Further evidence of this is provided by the extreme paucity of the terrestrial vertebrate fauna, represented by one small species of lizard, whose accidental introduction by man seems beyond doubt.

The absence of a definite surface drainage system, shallowness of the soil, and the generally extremely youthful surface physiography, suggest an age correlation with the unmodified volcanic areas of the Western District, such as Tower Hill, Koroit, which is regarded as not older than Upper Pleistocene.

Drift Material.—Amongst the locally-derived basalt pebbles of the shingle beaches of the western coast, numerous pebbles of rocks foreign to the island are found.

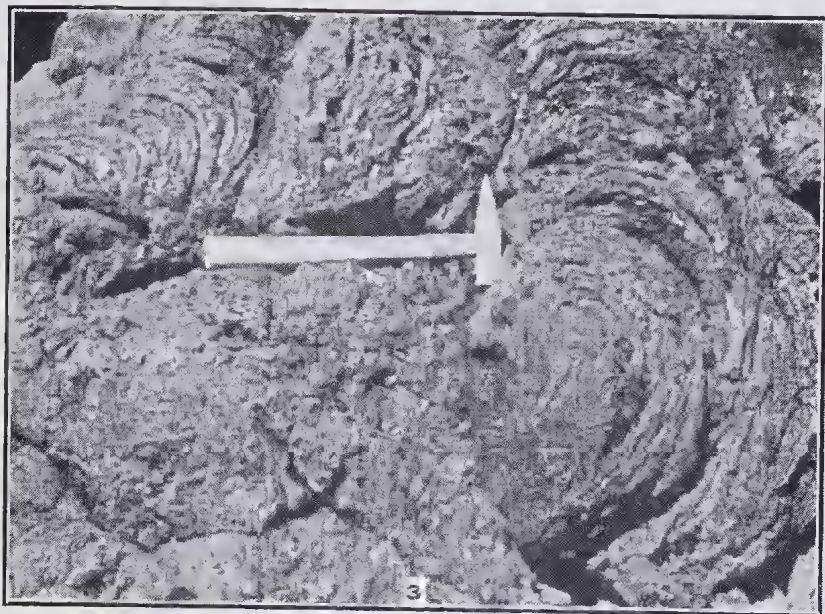
The most numerous of these are nodules of flint. In the hand specimen, indeterminate remains of Bryozoa can be seen in section, and the nodules have the white, calcareous, granular,



Lavas of Lady Julia Percy Island.







Lavas of Lady Julia Percy Island.





outer crust, typical of those found in the Miocene bryozoan limestones, outcropping along the western coast of Victoria, from which they cannot be distinguished. Occasional fragments of bryozoan limestone also occur.

Sporadic pebbles of porphyry, similar in type to the red-brown porphyries of Grange Burn Creek, Hamilton, also occur. At Hamilton these porphyries are directly overlain by the Lower Miocene marls and bryozoan limestones. It is therefore not improbable that similar relations occur on the sea floor between the island and the mainland.

Guano was taken some years ago from the Guano Cave in Seal Bay, where it apparently formed a deposit about 10-15 feet thick, almost completely filling the cave. Samples taken consist of a brown crystalline powder, analysis of which showed a high percentage of calcium phosphate with small amounts of iron and  $\text{CO}_2$ .

### **Explanation of Plates.**

#### **Plate XIX.**

Fig. 1.—Cliff section 5 chains south of Dinghy Cove, showing boulder tuff and overlying basalt flows.

Fig. 2.—Detailed view of boulder tuff and matrix 3 chains south of Dinghy Cove.

#### **Plate XX.**

Fig. 3.—Ropy basalt on the seaward slope of McCoy Platform.

Fig. 4.—The tuff cone and vent initiating the later vulcanicity, seen in section on the western side of Horseshoe Bay.

5. *Petrology.*

By EUPHEMIA A. McIVER, B.Sc.

The rocks of Lady Julia Percy Island fall into three main groups, viz.: (a) the volcanic rocks of which the island is entirely built up, (b) the drift material which occurs as well rounded pebbles in the shingle, and which has probably been derived from the sea floor between the island and the mainland, and (c) tektites.

**A. Volcanic Rocks.**

The sequence established in the field is as follows:—

3. Iddingsite-labradorite-basalt, comprising flows 2-6, over 80 feet thick.

2. Olivine-labradorite-basalt, flow 1, 10-20 feet thick.

1. Boulder tuff, 30 feet thick.

Thin and irregular bands of tuff occur between the successive flows in most cases.

## 1. BOULDER TUFF.

The boulders consist of comparatively thick tachylytic shells grading inwards into a dense basalt. The outer margin of the tachylytic shell contains a few large olivine phenocrysts with numerous small olivine crystals and plagioclase laths in a groundmass of green-brown glass, the latter constituting about 80 per cent. of the rock. No magnetite occurs. The plagioclase is labradorite ( $Ab_{33}$ ). Two generations of olivine may be distinguished, an older group consisting of large crystals very much corroded around the edges and along cracks so that often a mere skeleton remains (Fig. 1B), and a younger group of small olivine crystals with well preserved crystal boundaries (Fig. 1B).

Towards the centres of the boulders the olivine and felspar crystals increase in size and number, the olivine is often iddingsitized along its margins, and the glassy groundmass contains abundant magnetite globules which tend to segregate around the margins of vesicles and in clots throughout the glass (Fig. 1C), showing that the magnetite has begun to crystallize at a late stage. This material resembles the iddingsite-labradorite-basalt (Footsray type), described by McNerny (1929).

The fact that iddingsite occurs in the inner zones while it is absent nearer the surface of the boulders, shows that the rate of cooling has been an important factor in its production: the cooling near the surface has been sufficiently rapid to prevent both the oxidation of the iron in the olivine and the introduction of more iron, two important reactions in the formation of iddingsite.

The matrix of the boulder tuff is a tuffaceous material composed chiefly of small fragments of tachylytic basalt, brown glass, halloysite, and ash.

The tachylytic and ropy lavas contain abundant amygdulæ completely or partly filled with calcium carbonate, in the form of mammillary calcite with concentric colour bands, "nail head" crystals of calcite or aragonite, generally as aggregates of radially arranged acicular crystals.

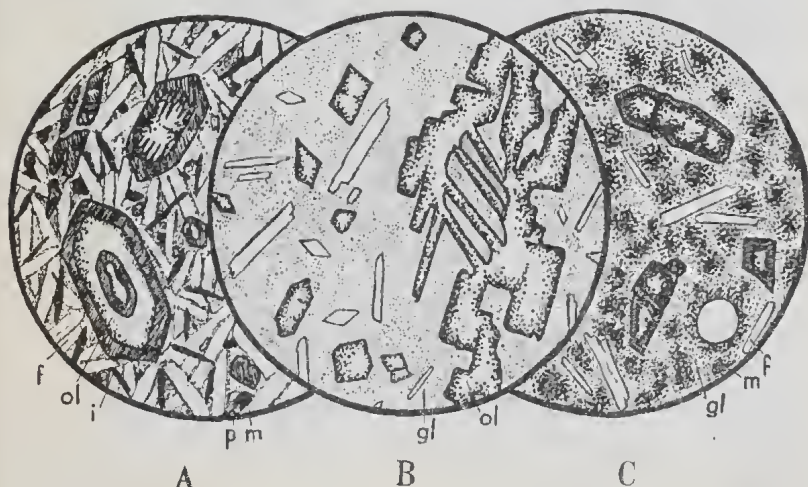


Fig. 1.—A. Iddingsite-labradorite-basalt; B. Tachylyte from Boulder Tuff; C. Tachylyte from Boulder Tuff; f—felspar, ol—olivine, i—iddingsite, p—pyroxene, m—magnetite, gl—glass.

## 2. OLIVINE-LABRADORITE-BASALT—FLOW 1.

This is a medium-grained basalt in which large phenocrysts of olivine occur in a groundmass of felspar laths (labradorite), purplish-grey titanite, iron ores—mainly ilmenite in the form of grains and rods—a little olivine, and abundant greenish-brown glass. There has been no iddingsitization, but partial resorption of olivine has occurred. The glass is free from iron ore, showing that the latter has crystallized at an early stage and that its crystallization was complete before the glass solidified.

## 3. IDDINGSITE-LABRADORITE-BASALT—FLOWS 2-6.

The five later flows possess the same general characteristics. They are medium in grain, and contain abundant phenocrysts of olivine which show no signs of corrosion, but are iddingsitized either completely or round their margins and along cracks. In some cases the junction between the iddingsite and the olivine core is fibrous (Fig. 1A). Occasionally a core of olivine is surrounded by iddingsite, followed by a zone of olivine, and finally by an outer zone of iddingsite, indicating an alternation in olivine and iddingsite-forming conditions (Fig. 1A). There are no pyroxene phenocrysts. The groundmass consists of laths

of labradorite ( $\text{Ab}_{37}$ ), small grains of greyish-green augite, irregular patches of iddingsite after olivine, and grains and rods of iron ores.

Flow 6 includes small, approximately spherical patches of coarser grained basalt, containing no olivine, and surrounded by well defined rings of partly resorbed minerals. These are probably xenoliths.

At Landslip Point, just above the level of Flow 1, a band of tuff, about 4 feet thick, occurs. This is traversed by narrow vertical sheets of denser resistant material. Microscopic examination of the denser material shows it to be a fresh basalt with all the characteristics of the iddingsite-labradorite-basalts described above, and that there has been no introduction of secondary materials from solutions. The flow 2 basalt has therefore filled cracks in the tuff between flows 1 and 2.

#### 4. TUFF.

The tuff bands are all of the same general character, consisting of fragments of tachylytic and crystalline basalt and green-brown glass, often sub-angular or rounded, in a yellow matrix of ash and halloysite. The various tuffs differ only in the percentage and size of the included fragments. At Thunder Point, the scoria show partial replacement by calcite, while the tuff which forms the matrix, and through which solutions have been able to pass more readily, has been very extensively replaced.

Secondary rocks, whose formation has been associated with the weathering of the basalt, include buckshot gravel and clays, with varying percentages of iron. These are developed in small quantities on the surface of the island, and consist of abundant small nodules of limonite in an earthy matrix ranging from a deep red brown material rich in iron, to a creamy-white bauxitic material. These rocks probably result from decomposition of basalt near the surface and introduction of hydrated oxides derived from the underlying basalt by ground water, and brought to the surface by capillarity during dry periods.

#### B. Drift Material.

This is most abundant in the shingle of Dinghy Cove and Seal Bay. The following rock types were recorded:—

##### 1. SPHERULITIC FELSPAR PORPHYRY.

Large phenocrysts of red orthoclase, spherulites and green biotite largely replaced by chlorite and magnetite, occur in a fine grained groundmass of feldspar, biotite and magnetite. The nature of the spherulites varies; some, probably those formed first, are perfect in shape, and no microliths can be distinguished, while others containing radiating microliths of a black mineral.



probably iron ore, often surround a felspar crystal as nucleus and invariably have irregular boundaries due probably to their formation being at a later stage than the former type (Fig. 2B).

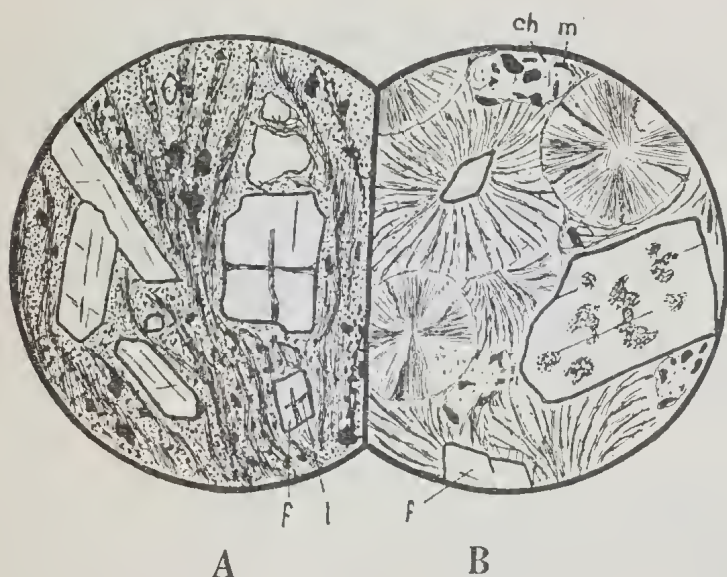


Fig. 2.—A. Felspar porphyry; B. Spherulitic felspar porphyry; f—felspar, l—limonite, ch—chlorite, m—magnetite.

## 2. FELSPAR PORPHYRY (Fig. 2A).

Large phenocrysts of orthoclase, often saussuritized, and abundant magnetite grains occur in a groundmass which shows definite flow structure, and which has been largely replaced by hematite. Hematite has also been introduced along the cleavage cracks of the felspar phenocrysts. Where lenticular patches of unreplaced groundmass occur the latter is seen to be very fine grained and to consist of felspar, quartz (?), chlorite and magnetite. The hematite imparts a dark purplish-red colour to the rock.

## 3. GRANOPHYRE.

This is a light grey rock consisting of granophyric intergrowths of quartz and orthoclase, much magnetite and chlorite replacing biotite and preserving in general the fibrous structure of the latter, and individual crystals of quartz and of saussuritized felspar.

## 4. FORAMINIFERAL LIMESTONE.

This is buff in colour, and consists entirely of crystalline calcite and tests stained with limonite. Under the microscope numerous tests of Foraminifera, of which *Globigerina*, *Cibicides* and *Textularia* are the most abundant, were distinguished.

## 5. FLINT.

Abundant large irregular nodules of grey flint with a white calcareous crust form the bulk of the drift material.

**C. Tektites.**

Two tektites (Australites) were found in the vicinity of Square Reef. As australites have been recorded from several areas in south-eastern Australia and are particularly abundant in a zone extending from Portland on the west to Warrnambool on the east, their occurrence on Lady Julia Percy Island, which falls within the limits of this zone, is to be expected. The finding of only two specimens is probably due to the fact that the growth of bracken rather than a sparse distribution prevents their detection. The fact that both specimens are rather worn suggests that their occurrence is not particularly recent. Their specific gravity falls within the normal range, which varies from about 2.3 to 2.6.

## DETAILED DESCRIPTION.

Specimen 1. Univ. Coll. No. 3023.

Classification.—This is referred to the button type, as there still remains approximately one-tenth of the flange. The rim is well defined; diameter 1.40 cm.; thickness 0.78 cm.; specific gravity 2.44. Anterior surface; this side shows two well-defined concentric flow ridges, and within the smaller of these, in a sub-central position, occur flow grooves. Posterior surface; this is closely pitted and near the margin shows distinct flow lines.

Specimen 2. Univ. Coll. No. 3024.

Classification.—As the diameter of this specimen varies slightly, the maximum being 1.30 cm., and the minimum being 1.13 cm., it tends toward the oval type rather than the true lens. The rim is well defined, and there is only a very small remnant of the flange; diameter, minimum 1.13 cm., maximum 1.30 cm.; thickness, 0.68 cm.; specific gravity, 2.52. Anterior surface; there are two concentric flow rings. Posterior surface; fairly close pitting occurs, and in one area near the rim there are two short flow grooves. Under the lens numerous flow lines are distinguishable.

**Reference.**

- McINERNY, KATHLEEN, 1929. The Building Stones of Victoria, Part II., The Igneous Rocks. *Proc. Roy. Soc. Vic.*, n.s., xli. (2), 1929, pp. 121-159.

## 6. *Vegetation.*

By A. G. EDMONDS.

### **Soil.**

The soil is black and very rich in organic matter, but exceedingly shallow. It is loamy in texture, excellently drained, and apparently quite fertile. It is of slightly acid reaction. Detailed analyses are given in section 7.

### **Rainfall.**

The rainfall may probably be taken as approximately equal to that of the neighbouring mainland (30 inches approximately) with reliability of about 15% average variation from the mean.

### **Wind.**

During our short stay, the island was continually under the effects of either north, south, or south-east winds, varying in intensity from mild winds to most intense storms, during which spray was blown over the island.

The effect on growth is twofold. Firstly, winds promote the loss of moisture from the plants and the shallow loamy soil. The significance of the latter is complicated by added moisture as spray, and the relatively high percentage of soil colloids. Secondly, it has a very great inhibiting physical effect on the growth of vegetation.

### **Vegetation.**

Vegetation found on the island can be divided into six communities:—

- (1) Grassland.
- (2) Fernland.
- (3) *Senecio* association.
- (4) Seasonal swampland.
- (5) *Mesembryanthemum* association.
- (6) Celery society.

The time of our stay was a very dry one. There were no shrubs or trees to be found on the island, nor would they be expected, as the constant high winds; together with the shallowness of the soil on this high and most exposed place, would surely inhibit all such growth.

#### GRASSLAND.

This constitutes about a third of the area, the predominant grass being *Calamagrostis filiformis* ("blown grass"), a grass of little flag and short thin leaves. Ewart, in his *Flora of Victoria*, gives it as "A common, glabrous, short-lived perennial, drying off in the summer, being a good fodder plant."

*Aira caryophyllea* (silvery hair grass) was fairly common, and formed, together with the blown grass, a mat of dried inflorescences over the surface.

*Briza minor* (shell grass) was recognized only from empty inflorescences. It was sparse.

Other plants present were *Anagallis arvensis* (scarlet pimpernel) and *Erythraea spicata*, one plant of which was found.

The absence of forms such as *Danthonia* and *Stipa*, prevalent on the mainland, is indeed singular.

#### FERNLAND.

This covers about one-third of the island, consisting of a practically pure and very dense colony of dwarfed (12-18 inches) plants of *Pteridium aquilinum* (bracken fern).

The rhizomes were set very deep in the soil, and their decay possibly accounts for the high humus content of the soil. It may be that there is a fluctuating balance between grassland and fernland. *Calamagrostis filiformis* was found in association in places. Other plants recorded were *Juncus pallidus* (rare) and *Juncus bufonius* (very rare). The fernland is the chief location for rabbit burrows.

#### SENECIO ASSOCIATION.

This covers an extensive area, mainly on the west of the island in the vicinity of the rookeries. It also is inhabited by rabbits. Its chief constituent was *Senecio latus* which is widespread in Victoria, being usually found on sandy loams. *Calamagrostis filiformis* was also present, and *Carduus pycnocephalus* (shore thistle) had also been introduced in some parts from the mainland.

#### SEASONAL SWAMPLAND.

A small patch of swamp occurs in the middle of the island, and is much frequented by rabbits. The association consists almost exclusively of *Chenopodium glaucum*, but *Anagallis arvensis* is prevalent on the edges. This is reported as a poisonous weed usually avoided by stock. It contains saponin, but is readily eaten by the rabbits.

#### MESEMBRYANTHEMUM ASSOCIATION.

This is restricted to the south of the island, and enjoys better drainage. Dead patches of this plant may probably account for the high humus content of the soil in other parts.

No reason for the death of this *Mesembryanthemum* could be seen. The sole constituents were *Mesembryanthemum aciculare* and *Dichondra repens*.

CELERY SOCIETY.

A small patch of *Apium australis* (sea celery) was found at the south end of the island.

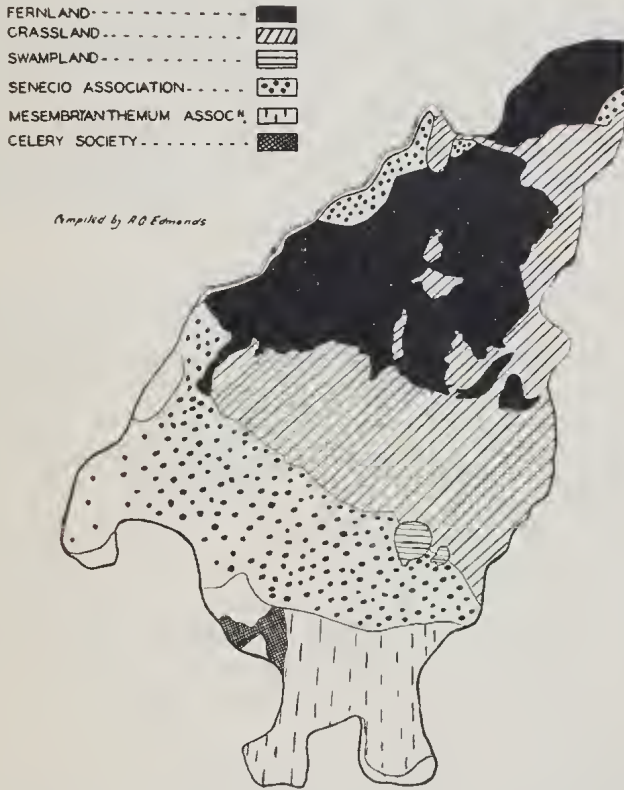


Fig. 1. Vegetation Survey Map of Lady Julia Percy Island.



## 7. Soil.

By A. G. EDMONDS.

## MECHANICAL ANALYSIS.

The soil is of a very shallow (6 in.-24 in.) and rocky nature. The texture of the soil in the main is, as indicated in the table below, that of a fine sandy loam. The swamp soil, however, is much heavier.

Gravel was found throughout the soil, and in parts covers the surface. Forming not more than 5 per cent., this gravel consists of partially decomposed basalt rock in the main, but also includes some concretions of hydrated ferric oxide (buckshot) distributed in depth.

TABLE.—MECHANICAL ANALYSIS OF SOILS OF VEGETATION TYPES.

	Fernland.		Grass-land.	Seasonal Swamp-land.	Senecio Asso-ciation.	Mesembryanthemum Association.		
Horizon (depth in inches) ..	0-8.	8-11.	0-6.	0-8.	0-14.	0-9.	9-18.	18-22.
Soil Colour.	Black.	Dark Brown.	Dark Grey.	Light Grey.	Black-brown.	Black.	Dark Brown.	Red Brown.
	%	%	%	%	%	%	%	%
Coarse sand < 2.0 mm. ..	20.6	24.2	17.2	5.4	24.6	18.7	28.8	7.9
Fine sand < .2 mm. ..	30.4	26.8	20.8	21.9	22.1	28.3	28.1	26.1
Silt and clay < .02 mm. ..	18.4	20.5	37.4	55.1	24.9	28.1	27.0	55.0
Moisture ..	12.5	11.2	12.6	6.4	14.3	14.6	14.0	11.0
Organic matter ..	18.1	17.3	12.0	11.2	14.1	10.3	2.1	..
Reaction pH ..	5.7	5.7	4.8	5.2	5.5	6.0	6.5	6.7

The table shows the soils to be on the acid side of neutrality with a pH range of 4.8-6.7. The only soil on which *Azotobacter* grew well was the *Mesembryanthemum*, which has a pH 6.0-6.4, though this difference may be due to the different mineralogical compositions of the soil as much as to pH.

## ORGANIC MATTER.

The organic content of the soil was particularly high in all samples, due presumably to very good plant growth. Plants were not growing, however, at our time of visit. The specific nature of the flora might also assist in accounting for the high percentage of organic matter.

## FINE SAND MINERALS.

A microscopic analysis of the fine sand fractions, kindly made by Miss Ann Nicholls, showed magnetite to be extremely abundant, constituting about 50-75 per cent. of the minerals. Augite, plagioclase, and olivine were common, being in the form of fresh, irregular crystals.

Quartz, found as round grains, was fairly scarce, constituting about 10 per cent. of the sand fraction. The presence of the quartz is apparently the result of wind-blown material from neighbouring beaches. Zircon, presumably from the same source, was present in small quantities.

Biotite occurred in all samples, being common in the *Mesembryanthemum* soil, and very rare in the others.

The swampland soil differed markedly from the above types. Sponge spicules constituted the large proportion (about 80 per cent.) of the fine sand. The remaining 20 per cent. consisted mainly of quartz with magnetite, augite, plagioclase, olivine, and biotite in small amounts.

#### SOIL DEVELOPMENT.

The presence of augite in the fine sand, together with the shallowness of the soil and poor development of any profile, points to the very immature state of the soil.

Conditions of drainage at the island are excellent, and the formation of soil consists of an initial leaching of soluble bases mainly to the sea, and possibly in part to the swamp.

As soon as formed, silt and clay particles, together with run-off water are washed either into the swamp or the sea.

The origin of ironstone concretions is obscure; they may have been formed during geological weathering or in the process of soil formation.

A deeper and more mature profile has been developed, due to leaching down and deposition below of clay.

Material from which the swamp area has been formed evidently consists of finer fractions washed down from slopes.

#### GENERAL FERTILITY.

The texture, mode of development, and fertility of the soil on the island are apparently very similar to those of the Stony Rise soils on the mainland, described as Corangamite Stony Loam (1).

The Stony Rise soils are much more fertile and immature than the basaltic soils of the Western District generally.

From the abundance of primary minerals and organic matter it is to be concluded that the island soil is more fertile than the typical mainland soils on basalt, although shallowness of soil, distance from markets, and exposure to winds would probably inhibit any form of cultivation, while the presence of the large rabbit population is probably responsible for the paucity of the flora.

#### Reference.

1. LEEPER, G. W., ANN NICHOLLS, and S. M. WADHAM, 1936. Soil and Pasture Studies in the Mount Gellibrand Area, Western District of Victoria. *Proc. Roy. Soc. Vic. (n.s.)*, xlix. (1), 77.

## 8. Soil Bacteriology.

By D. J. W. SMITH, B.Sc.

To determine the presence or absence of nitrogen-fixing and nitrifying bacteria in the soils of Lady Julia Percy Island, laboratory investigations were made upon samples taken from the five of the botanical areas represented.

1. *a.* An estimation of the *Azotobacter* population was obtained by counts upon silico-gels impregnated with the appropriate nutrients.
- b.* The "soil-plaque" method was used for detecting their activity. In particular, any deficiency of Calcium or Phosphorus is revealed by this method.
2. An attempt was made to detect the symbiotic nitrogen fixers by the growth of clover and lucerne seedlings in flower pots and culture tubes. In the pot experiments, sterile seeds were sown in washed sterile sand, and inoculated with soil washings. As a control, a similar series of pots were inoculated with a suspension of the appropriate strains of *B. radicola*. A parallel experiment was performed in tubes of nitrogen-free mineral agar; the seeds being coated with a layer of the soil under test.
3. The standard method of silico-gels impregnated with mineral salts, providing nitrogen in the form of (*a*) ammonium sulphate and (*b*) potassium nitrate, was used for the detection of nitrite and nitrate-producing organisms respectively.

As a first step, pH determinations were made on the five samples under examination.

## Results of Tests.

The soil samples tested are indicated below by the letters A to E, as follows:—A—fernland: B—grassland: C—swampland: D—*Senecio* association: E—*Mesembryanthemum* association.

## IA. AZOTOBACTER COUNT.

Silico-gels (prepared as set out in the appendix) were impregnated per plate with—

2 ccs. Saline A, .1 gm. Mannite, .02 gm. Calcium Carbonate, inoculated with grains of soil, and incubated at 27°C.

Table I shows that there was a considerable variation in bacterial numbers in the different samples, *Azotobacter* being almost, if not entirely, absent from A, B, and C. This is most probably to be correlated with the low pH values of some of the soils, soil acidity being more harmful to *Azotobacter* than to most organisms.

TABLE 1.

Time.	A.		B.		C.		D.		E.		Control.	
	pH 5.70.		pH 4.84.		pH 5.19.		pH 5.72.		pH 6.32.		Garden Soil.	
	i.	ii.	i.	ii.	i.	ii.	i.	ii.	i.	ii.	i.	ii.
72 hours	—	—	—	—	—	—	—	—	+	+	++	++
8 days	—	—	mould	mould	mould	mould	+	+	++	++	++	++
			mould	mould	3 colonies mould	mould						

## 1B. SOIL PLAQUES.

(b) From each sample, 200 gms. of sifted soil were taken and mixed with 2 gms. of mannite; the whole was divided into four, and the parts treated as below:

*O. Control*—moistened with distilled water.

*P.* Moistened with a solution containing .6 gms.  $\text{NaHPO}_4$  and .33 gms. of  $\text{NaH}_2\text{PO}_4$  per litre, giving a .1 per cent. sol. of phosphate pH7.

*Ca.* 1.5 gms. of  $\text{CaCO}_3$  added, and moistened with distilled water.

*Ca and P.* 1.5 gms. of  $\text{CaCO}_3$  added, and moistened with phosphate solution.

Each sample was ground up finely in a mortar, pressed down smoothly in a petri-dish, and the surface glazed with kaolin.

Plaques were incubated at  $27^\circ\text{C}$ .

In those soils having a very low pH, the soil-plaque test showed little or no growth even in the presence of phosphate and calcium carbonate; this failure was probably due to the scarcity of *Azotobacter* cells originally present in such soils; this supports the finding in 1 (a). Sample "E" (Plate XXI.), possessing a high grade *Azotobacter* flora, gave the most prolific growth when phosphorus was added, indicating a deficiency of available phosphate, which is common in volcanic soils of the type under test. The requirements of crop plants and of *Azotobacter* are similar as regards the need for soluble phosphate. Addition of  $\text{CaCO}_3$  in the more acid samples "B" and "C," produced a slight growth after a long period of incubation. In "E," however, it slightly inhibited growth.

## 2. SYMBIOTIC NITROGEN-FIXERS.

The formation of root-nodules upon lucerne and clover plants was used as an index of the *B. radicola* population in the soil. New 6-inch flower-pots were thoroughly washed with phenyle, rinsed with distilled water and filled with washed sand previously autoclaved for 4 hours. Lucerne and clover seeds, sterilized

TABLE 2.

Time.	Garden Soil.					A.				B.				C.				D.				E.
	O.	P.	Ca.	Ca-P.	O.	P.	Ca.	Ca-P.	O.	P.	Ca.	Ca-P.	O.	P.	Ca.	Ca-P.	O.	P.	Ca.	Ca-P.	86 Hours Incubation.	
24 hours ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	++ Few scattered colonies	
48 hours ..	+	++	+	++	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+++ Thick jelly like growth covering plaque	
86 hours ..	+	+++	++	+++	—	—	—	—	—	—	colonies 6	7	—	—	—	—	—	—	—	—	++ Fine jelly reticulation of coalescing colonies	
10 days ..	+	+++	++	+++	colonies 25	—	—	—	—	—	++	6	—	—	—	—	++ 30-50	—	—	Ca and P	++ Coarse jelly reticulation of coalescing colonies	



by washing with 1/1000  $\text{HgCl}_2$  in 90 per cent. alcohol were sown, and the pots moistened with a watery extract (50 cc. water with 15 gms. soil) of the soil samples. A similar series of control pots was inoculated with an aqueous suspension of the appropriate *B. radiculicola* type. The seedlings were grown in the glass-house over a period of  $2\frac{1}{2}$  months. In addition to normal watering, each pot was moistened twice per week with a nitrogen-free mineral solution.

TABLE 3.

## TEST PLANTS.

A.		B.		C.		D.		E.		Garden Soil.		Sterile Sand.	
L.	C.	L.	C.	L.	C.	L.	C.	L.	C.	L.	C.	L.	C.
-	+	-	-	-	-	+	-	+	-	+	+	-	-

L = Lucerne.      C = Clover.

## CONTROL PLANTS.

A.		B.		C.		D.		E.		Garden Soil.		Sterile Sand.	
L.	C.	L.	C.	L.	C.	L.	C.	L.	C.	L.	C.	L.	C.
+	+	+	+	+	+	-	+	+	+	+	+	+	+

L = Lucerne.      C = Clover.

The control plants showed a much more rapid initial growth, and in general produced the sturdier seedlings. Some of the "test" plants began to yellow off after 6 or 7 weeks, and when examined later, these proved to be without nodules. It was noticed that plants possessing nodules had a much shorter and sturdier root system than those with which nodule formation did not take place.

The experiment shows that *B. radiculicola* "clover" strain is present only in sample "A" taken from the bracken area. The "lucerne" strain is present in samples "D" and "E." Both types were present in garden soil, and both were absent from the sterile sand medium without soil-washings.

A further test was made by using tubes of a nitrogen-free mineral agar as the medium, in place of sterile sand. The seeds

were first sterilized, then coated with a layer of the soil to be tested, and sown four to a tube. In the control tubes a platinum loop full of the appropriate *radicola* type was placed by each seed. Rapid growth occurred in the first week, but before the roots were sufficiently developed for nodule formation to take place, a thick growth of moulds occurred in most of the tubes, and the seedlings died off.

### 3. NITRIFIERS.

#### *Nitrite formers.*

Standard silico-gels were used. Each plate impregnated with 2 ccs. Saline B, 1 cc. 5 per cent.  $(\text{NH}_4)_2\text{SO}_4$ , and enamelled with a thin cream of  $\text{MgCO}_3$  in water. The plates were inoculated with soil, and incubated at  $27^\circ\text{C}$ .

#### *Nitrate formers.*

Silico-gels impregnated with 2 ccs. Saline B, 1 cc. 3 per cent.  $\text{KNO}_2$  sol., enamelled with a thin cream of  $\text{CaCO}_3$  and kaolin water. Inoculated and incubated at  $27^\circ\text{C}$ .

At the first attempt no growth was obtained after a period of 3 weeks incubation. A second series of plates were then inoculated from samples which had been previously moistened with the  $(\text{NH}_4)_2\text{SO}_4$  and the  $\text{KNO}_2$  solutions respectively, and incubated at  $27^\circ\text{C}$ . for 24 hours. An abundant growth of "nitrite" producers was obtained from all samples, but "nitrate" formers could not be isolated.

### Conclusion.

Sample E, representing soil derived from a particular lava flow, stands in contrast with the rest of the island soil in the possession of a very rich flora of aerobic nitrogen fixers, i.e., *Azotobacter* cells. The apparently random distribution of symbiotic "fixers" may well be associated with the complete absence of any leguminous plants from the island.

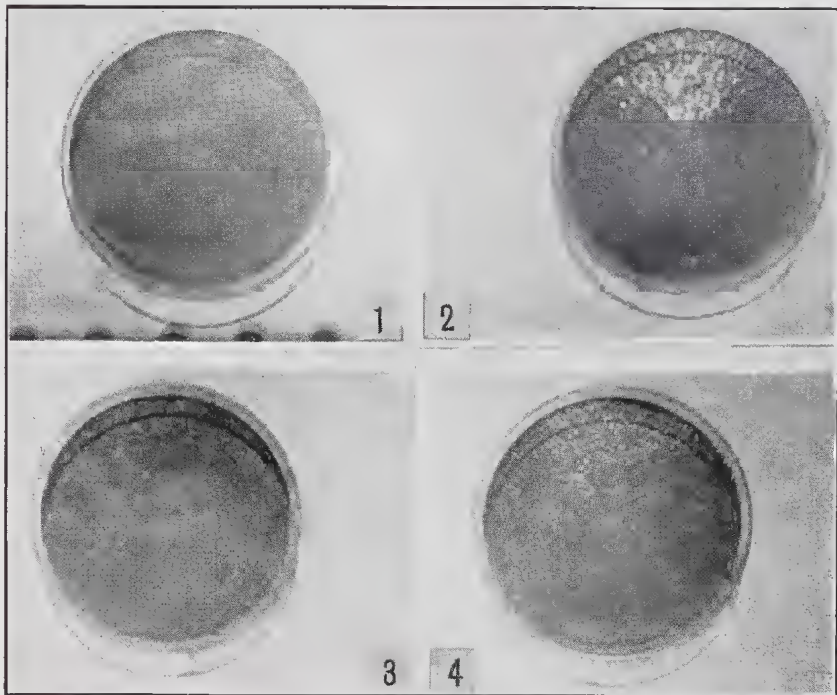
Although nitrate producing organisms could not be isolated, the occurrence of nitrite formers in all samples would indicate that the soil possesses a normal nitrifying flora.

### Appendix.

#### PREPARATION OF SILICO-GELS.

Equal volumes of Sodium silicate Sp.gr. 1.075 and Hydrochloric acid Sp.gr. 1.1725, mixed together. 30 ccs. of mixture per plate.





Photographs of Soil Plaques.

*Mineral Salts Solutions.*

<i>Saline "A."</i>			<i>Saline "B."</i>		
$\text{KH}_2\text{PO}_4$	..	1.0 gm.	$\text{K}_2\text{HPO}_4$	..	0.5 gms.
$\text{MgSO}_4$	..	0.5 gm.	$\text{MgSO}_4$	..	0.5 gms.
$\text{NaCl}$	..	0.5 gm.	$\text{NaCl}$	..	0.3 gms.
$\text{FeSO}_4$	..	0.02 gm.	$\text{FeSO}_4$	..	0.02 gms.
$\text{MnSO}_4$	..	0.02 gm.	$\text{MnSO}_4$	..	0.02 gms.
$\text{H}_2\text{O}$ dist.	..	200 ccs.	Traces of Zn.Mg.Al. from tap-water.		
		pH 7.3	$\text{H}_2\text{O}$ dist.	..	200 ccs.

<i>Watering Solution.</i>			<i>"N" Free Mineral Agar.</i>		
$\text{KCl}$	..	10 gms.	$\text{K}_2\text{HPO}_4$	..	0.5 gms.
$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	..	2.5 gms.	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	..	0.2 gms.
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	..	2.5 gms.	$\text{NaCl}$	..	0.1 gms.
$\text{Ca}_3(\text{PO}_4)_2$	..	2.5 gms.	$\text{Ca}_3(\text{PO}_4)_2$	..	2.0 gms.
$\text{FePO}_4$	..	2.5 gms.	$\text{FeCl}_3$	..	0.01 gms.
Use 1.5 gms. in 100 ccs. of water.			Agar	..	10.0 gms.
			Water	..	1 litre.

**Description of Plate XXI.**

Soil Plaques of Sample "E," illustrating the response of *Azotobacter* to added calcium carbonate and phosphate: 1. Control; 2. phosphate added; 3. calcium carbonate added; 4. phosphate and calcium carbonate added.



## 9. List of Vascular Plants.

By R. T. PATTON, D.Sc.

		SPECIES.	REMARKS.
Polypodiaceae	..	<i>Asplenium scleroprium</i> Honrb. et Jacq. <i>Pteridium aquilinum</i> Kuhn.	In cave, south end
Gramineae	..	<i>Phalaris minor</i> Retz. <i>Poa caespitosa</i> G. Forst. .. <i>Dichelachne crinita</i> (L.) Hk.f. <i>Calamagrostis filiformis</i> Pilg. <i>Hordeum murinum</i> L. ..	On cliffs On cliffs
Cyperaceae	..	<i>Scirpus nodosus</i> Rottb. ..	"
Juncaceae	..	<i>Juncus pallidus</i> R.Br.	
Urticaceae	..	<i>Urtica dioica</i> L.	
Chenopodiaceae		<i>Chenopodium glaucum</i> L. .. <i>Enchylaena tomentosa</i> R.Br. .. <i>Rhagodia baccata</i> Moq. .. <i>Salicornia australis</i> Sol. ..	In swamp On cliffs "Near spring
Aizoaceae	..	<i>Mesembryanthemum aequilaterale</i> Haw. <i>M. australe</i> Sol. ..	High ground, south end On cliffs
Caryophyllaceae		<i>Polycarpon tetraphyllum</i> L. <i>Sagina apetala</i> L. .. <i>Spergularia rubra</i> Presl. ..	South end Near spring
Cruciferae	..	<i>Lepidium foliosum</i> Desv. ..	On cliffs
Geraniaceae	..	<i>Pelargonium australe</i> Willd. ..	"
Onagraceae	..	<i>Epilobium junceum</i> G. Forst.	
Umbelliferae	..	<i>Apium australe</i> Thou. ..	High ground, south end
Gentianaceae	..	<i>Erythraeu spicata</i> Pers.	
Apocynaceae	..	<i>Alyxia buxifolia</i> R.Br. ..	On cliffs
Convolvulaceae	..	<i>Dichondra repens</i> R. & G. Forster ..	Plentiful among <i>Mesembryanthemum aequilaterale</i>
Solanaceae	..	<i>Solanum aviculare</i> G. Forst. ..	On cliffs
Compositae	..	<i>Calocephalus Brownii</i> F.v.M. .. <i>Gnaphalium indutum</i> Hk. f. <i>Cotula Coronopifolia</i> L. .. <i>Senecio lautus</i> Sol. <i>Carduus pycnocephalus</i> Jacq.	"Near spring

10. List of Algae.

By R. T. PATTON, D.Sc.

CHLOROPHYCEAE.

<i>Caulerpa hypnoides</i> Ag.	Caulerpaceae
<i>Codium tomentosum</i> Stackn.	Codiaceae
<i>Ulva lactuca</i> Linn.	Ulvaceae

PHAEOPHYCEAE.

<i>Ecklonia radiata</i> Ag.	Alariaceae
<i>Lobospora bicuspidata</i> Aresch.	Dictyotaceae
<i>Phyllospora comosa</i> Ag.	Fucaccae
<i>Seirococcus axillaris</i> Grev.	Fucaceae
<i>Zonaria crenata</i>	Dictyotaceae

RHODOPHYCEAE.

<i>Ballia callitricha</i> Ag.	Ceramiaceae
<i>B. scoparia</i> Harv.	Ceramiaceae
<i>Corallina</i> spp.	Corallinaceae
<i>Gelidium glandulaefolium</i> H. et H.	Gelidiaceae
<i>Laurencia clata</i> Harv.	Rhodomelaceae
<i>Nitophyllum</i> sp.	Delesseriaceae
<i>Nizyomenia australis</i> Sond.	Gelidiaceae
<i>Phacelocarpus Labillardieri</i> Ag.	Sphaerococcaceae
<i>Plocamium Preissianum</i> Sond.	Rhodymeniaceae

11. *Coelenterata*.

By MAURICE BLACKBURN, B.Sc.

## Class HYDROZOA.

Ten genera and twenty species of Calyptoblastea typical of the Bass Strait region were collected. The occurrence of gonothecae is indicated for those species in which they were found. The specimens were derived from three sources, viz.:—

Locality 1.—On seaweed dredged from 25 fathoms off West Cape.

Locality 2.—Drift material washed up between Seal Bay and Dinghy Cove.

Locality 3.—Forms growing in rock pools between West Cape and Dinghy Cove.

## Family CAMPANULARIIDAE.

## ORTHOPIYXIS MACROGONA (von Lendenfeld, 1884).

*Campanulina calyculata* var. *makrogona* von Lendenfeld, 1884. Proc. Linn. Soc. N.S.W., ix., p. 922.

*Orthopyxis macrogona* (von Lendenfeld), Bale, 1914, Proc. Roy. Soc. Vic., n.s., xxvii. (1), p. 77, pls. xi., xii.

Four specimens were found growing on the test of a tunicate (*Amaroucium* sp.). Although no gonangia were present the form has been referred to *O. macrogona* because of the square form of the hydrotheca in the broad aspect, which is a characteristic of this species. Loc. 3.

## CAMPANULARIA TINCTA (Hincks, 1861).

*Campanularia tincta* Hincks, 1861, Ann. Mag. Nat. Hist., ser. 3, vii., p. 280.

Loc. 1.

## Family CAMPANULINIDAE.

## THYROSCYPHUS MARGINATUS (Bale, 1884).

*Campanularia marginata* Bale, 1884, Aust. Mus. Cat. Hyd. Zooph., p. 54, pl. 1.

*Thyroscyphus marginatus* (Bale), 1914, loc. cit., p. 91.

Loc. 2.

## THYROSCYPHUS SIMPLEX (Lamouroux, 1816).

*Laomedea simplex* Lamouroux, 1816, Hist. Polyp. Corall. Flex., p. 206.

*Thyroscyphus simplex* (Lamouroux), Bale, 1915, Sci. Results Endeavour Exped., iii., p. 245.

Loc. 2.

## Family HALECIDAE.

OPHIODISSA FRAGILIS, sp. nov.

(Figs. 1A-D.)

Hydrorhiza a network of stout tubes; stem monosiphonic, maximum height about 15 mm., unbranched, fairly straight at the proximal end, but becoming more or less zigzag at the top, divided into internodes by oblique twists, the internodes varying somewhat in length and each bearing a hydrophore at the summit and being conspicuously twisted below.

Primary hydrophores alternate, borne on "peduncles" arising from the upper parts of the internodes and generally only very slightly ascending. (The term "peduncles" is used for convenience, these jointed processes probably representing the proximal ends of the hydrophores.) Peduncles jointed, the joints varying in number from two to four, each characterized by an internal constriction of the perisarc; frequently the peduncles are of very great length owing to the abnormal prolongation of one or more of the joints. Hydrophores bell-shaped, with an internal perisarc septum almost separating off the upper two-thirds of the cup. The row of bright points encircling the rim, a common feature in this family, appears in all cases to be absent. Secondary hydrophores occasionally are observed arising from the peduncles; a specimen shows one with an abnormally elongated series of proximal joints along which a hydrophore of the third order has arisen.

Sarcothecae, fairly large vase-shaped cups, each arising from the peduncle of a hydrophore. In some cases these were missing, possibly due to their having been broken off. One of the sarcothecae contained a partly extruded capitate dactylozoid typical of the genus.

Gonangia subspherical, arising at the junction between stem and peduncles, as well as stem and hydrorhiza.

This form was found living on the underside of a rock in a shallow pool in Dinghy Cove. The capitate dactylozoid definitely refers it to *Ophiodissa*. This form differs from all eight species of this genus except *O. caciniiformis* Ritchie in being wholly unbranched, although the structures described as branches for *O. gracilis* Fraser (and possibly others) may represent the elongated peduncles which appear as a variation in the present form. The twisted internodes, regular location of the sarcothecae, very slightly ascending peduncles and the character of the gonangia are distinctive.

Additional material from Balnarring, Western Port (coll. Stach and Tubb, May, 1936) agrees exactly with the types. However, despite their excellent preservation, only one sarcotheca was found on the fifteen colonies examined, indicating that the appearance of the cups on the peduncles is by no means regular.



Fig. 1.—*Ophiodissa fragilis*. A. Section of stem showing internodes bearing "peduncles" with primary and secondary hydrophore (left) and sarcotheca (right). B. Junction of stem and hydorrhiza showing gonangium, also "peduncle" with sarcotheca. C. Stem internode bearing primary hydrophore, elongated "peduncle" of secondary hydrophore and tertiary hydrophore. D. Junction of stem and peduncle of hydrophore, the latter bearing sarcotheca with dactylozoid. Mag. 40. Ped., elongated peduncle of secondary hydrophore; p.h., primary hydrophore; s., sarcotheca; s.h., secondary hydrophore; t.h., tertiary hydrophore.

Fig. 2.—*Sertularia bicuspidata*. Gonotheca. Mag. 20.



Family SERTULARIIDAE.

SERTULARIA ACUTA (Stechow, 1921).

*Sertularia loculosa* Bale (non Busk), 1884, *loc. cit.*, p. 91, pl. iv. Idem, 1913, *Proc. Roy. Soc. Vic.*, n.s., xxvi. (1), p. 121, pl. xiii.

*Tridentata acuta* Stechow, *Zool. Jahrb., Abt. f. Syst.*, xlvii., 1923, pp. 204, 206.

Loc. 1.

SERTULARIA PULCHELLA Thompson, 1879.

*Sertularia pulchella* Thompson, 1879, *Ann. Mag. Nat. Hist.*, ser. 5, iii., p. 108, pl. xviii., fig. iii.

Loc. 1.

SERTULARIA BICUSPIDATA Lamarck, 1816.

*Sertularia bicuspidata* Lamarck, *Hist. Anim. s. Vert.*, v., 1816, p. 121.

*Sertularia bicornis* Bale, 1881, *Journ. Micro. Soc. Vic.*, ii., p. 22, pl. xii., fig. iii.

The shoots, though pinnate, are extremely small, the maximum length being 3 mm. The gonothecae, not previously described, are regularly ovate, arising from the main stem by a short stalk; aperture circular, with an elevated rim; length of gonothecae about equal to that of three stem internodes.

Loc. 1.

SERTULARIA MCCALLUMI (Bartlett, 1907).

*Sertularella mccallumi* Bartlett, 1907, *Geelong Nat.*, ser. 2, iii. (4), p. 62.

*Sertularia mccallumi* (Bartlett), Bale, 1919, *Proc. Roy. Soc. Vic.*, n.s., xxxi. (2), p. 340, pl. xvi.

Loc. 1.

SERTULARELLA PEREGRINA Bale, 1926.

*Sertularella gaudichaudi* (Lamouroux), Bale, 1915, *loc. cit.*, p. 280.

*Sertularella peregrina* Bale, *Proc. Roy. Soc. Vic.*, n.s., xxxviii., 1926, p. 19, fig. iv.

This form was actively increasing by budding. The polyps exhibit a raised conical hypostome surrounded by a single circlet of about twenty delicate filiform tentacles.

Loc. 3.

SERTULARELLA ROBUSTA Coughtrey, 1875.

*Sertularella robusta* Coughtrey, 1875, *Trans. N.Z. Inst.*, viii., p. 300.

Trebilcock, 1928, *Proc. Roy. Soc. Vic.*, n.s., xli. (1), p. 16.

Previously recorded from New Zealand. If *S. microgona* von Lendenfeld and *S. angulosa* Bale are correctly referred to this species, the range must be extended to include Port Phillip. Trebilcock has already suggested this with regard to the latter species. Loc. 3, associated with *S. gaudichaudi*.

## SERTULARELLA INDIVISA Bale, 1881.

*Sertularella indivisa* Bale, 1881, *loc. cit.*, p. 24, pl. xii., fig. vii. Idem, 1915, *loc. cit.*

Hydrothecae smooth, rugae hardly discernible. Loc. 2.

## SERTULARELLA NEGLECTA Thompson, 1879.

*Sertularella neglecta* Thompson, 1879, *loc. cit.*, p. 100, pl. xvi., fig. 1.

Gonothecae abundant, borne near the middle of the pinnae. Loc. 1.

## Family SYNTHECIDAE.

## STEREOTHECA ELONGATA (Lamouroux, 1816).

*Sertularia elongata* Lamouroux, 1816, *loc. cit.*, p. 189, pl. v., fig. iii.

*Stereotheca elongata* (Lamouroux), Bale, 1924, *Trans. N.Z. Inst.*, lv., p. 252.

Very common. Gonothecae generally present. Loc. 2.

## Family PLUMULARIIDAE.

## Group ELEUTHEROPLEA.

## PLUMULARIA BALEI Bartlett, 1907.

*Plumularia balei* Bartlett, 1907, *loc. cit.*, p. 65.

Loc. 2.

## PLUMULARIA SETACEOIDES Bale, 1881.

*Plumularia setaceoides* Bale, 1881, *loc. cit.*, p. 40, pl. xv., fig. iv.

Loc. 2.

## PLUMULARIA GOLDSTEINI Bale, 1881.

*Plumularia goldsteini* Bale, 1881, *loc. cit.*, p. 41, pl. xv., fig. vii.

Loc. 1.

## PLUMULARIA SPINULOSA Bale, 1880.

*Plumularia spinulosa* Bale, 1880, *loc. cit.*, p. 42, pl. xv., fig. viii.

The terminal spine is rounded in these forms.

Loc. 1.

## Group STATOPIEA.

## AGLAOPHENIA DIVARICATA (Busk, 1852).

*Plumularia divaricata* Busk, 1852, *Voyage of "Rattlesnake,"* i., p. 398.

*Aglaophenia divaricata* (Busk), Bale, 1884, *loc. cit.*, p. 162.

Loc. 3.

## HALICORNARIA LONGIROSTRIS (Kirchenpauer, 1872).

*Aglaophenia longirostris* Kirchenpauer, 1872, *Abh. Ver. Hamburg*, v., 3, p.

*Halicornaria longirostris* (Kirchenpauer), Bale, 1884, *loc. cit.*, p. 181, pl. xiii.

Loc. 3.

## Class ANTHOZOA.

The Gorgonacean was dredged from 25 fathoms off West Cape. The Actinians were obtained from rock pools and shore platforms between Dinghy Cove and McCoy Platform and the coral was found in a dry and weathered condition in a joint plane at the top of McCoy Platform.

## Subclass ALCYONARIA.

## Order GORGONACEA.

## Family MELITODIDAE.

## CLATHRARIA (?) AKALYX Kukenthal, 1908.

*Clathraria akalyx* Kukenthal, 1908, Zool. Anzeiger, xxiii., p. 201.

The branching colony, attached to the Bryozoan, *Adeona grisea*, is about 18 cm. high and 14 cm. in its broadest aspect. The colour when dry is creamy white, the nodes being faintly tinged with red. Anastomosis of the branches occurs rarely.

The characters of the specimen agree with *Clathraria* and this form is tentatively referred to the sole Australian species of the genus, *C. akalyx*, in which the mode of branching is closely similar, the colour when alive being red. Previously known from Sharks Bay, Western Australia.

## Subclass ZOANTHARIA.

## Order ACTINIARIA.

The classification adopted is that of Haddon (1898, Trans. Roy. Dublin Soc., ser. 2, vi., p. 394) with the emendations of Stephenson (1922, Quart. Journ. Micro. Sci., lxvi., p. 265) for Actiniidae.

Many of these names are queried in the following list; this precaution has been taken in the absence, for comparison, of specimens from type localities.

## Family ACTINIIDAE.

## ACTINIA cf. EQUINA Linnaeus, 1767.

*Actinia equina* Linnaeus, 1767, Syst. Nat., ed. 12, p. 1088.

Extremely abundant on the shores of the island. Dissected specimens contained fertile gonads and embryos at various stages, some being liberated in large numbers through the mouths of the parents and becoming fixed to the rocks almost immediately. Because of its invariable dark red colour this form has been described from New Zealand as a separate species, *A. tenebrosa* Farquhar, 1898. There seems, however, no more justification for separating this form than for many other colour varieties of *A. equina*. Previously recorded from New Zealand and European waters; also E. Africa, St. Thomas, and Juan Fernandez.

## ANEMONIA cf. SULCATA (Pennant, 1766).

*Actinia sulcata* Pennant, 1766, A British Zoology.

*Anemonia sulcata* (Pennant), Milne-Edwards, 1857, Nat. Hist. Cor. Polypes, i., p. 233.

Average height of column in life about 6 cm.; average diameter of pedal disc from 10 to 12 cm. Column dull red in some specimens and green in others. Tentacles long and of a light brownish green colour. The external characters and weak (possibly absent) sphincter muscle confirm the identification. Previously recorded from European waters and Palestine.

## ANEMONIA OLIVACEA (Hutton, 1878).

*Anthea olivacea* Hutton, 1878, Trans. N.Z. Inst., xi., p. 312.

*Anemonia olivacea* (Hutton), Farquhar, 1898, Journ. Linn. Soc., xxvi., p. 527.

This common form occurred in various tonings of red, brown, orange and yellow, as well as the olive-green variety described from New Zealand. The puffy capitular rim and yellow stellate pattern on the oral disc confirm the identification. Previously known only from New Zealand.

## TEALIA cf. CRASSICORNIS (Muller, 1766).

*Actinia crassicornis* Muller, 1766, Zool. Dan. Prodrum, p. 231.

*Tealia crassicornis* (Muller), Gosse, 1858, Ann. Mag. Nat. Hist., ser. 3, i., p. 414.

Previously recorded from European waters, Canada, and Juan Fernandez.

## BUNODACTIS cf. INCONSPICUA (Hutton, 1878).

*Phymactis inconspicua* Hutton, 1878, loc. cit., p. 313.

*Bunodes inconspicua* (Hutton), Stuckey, 1908, Trans. N.Z. Inst., xli., p. 394.

A few specimens appear to belong to this species. Colour of column a glaucous olive green; tentacles dull purplish red. Average height of column 15 mm.; diameter of expanded oral disc about 15 mm. Verrucae of column only properly visible on the upper part; lower down the surface is much folded, the verrucae small and weak and the whole surface covered with a rough cuticular substance. The last character is an important feature of the species. Sections of the sphincter muscle reveal it to be rather less circumscribed than other workers suggest. The generic name *Bunodes* has been replaced by *Bunodactis* Verrill, 1899. Previously recorded from New Zealand.

Family SAGARTIIDAE.

SAGARTIA ALBOCINCTA (Hutton, 1878).

*Gregoria albocincta* Hutton, 1878, *loc. cit.*, p. 312.

*Sagartia albocincta* (Hutton), Stuckey, 1908, *loc. cit.*, p. 382.

These specimens exhibited typical coloration and internal structure. Acontia were emitted freely on the slightest disturbance. Mature gonads were found, but no embryonic stages. Previously recorded from New Zealand; also recently collected by me from Port Fairy and Western Port.

Family CORALLIMORPHIDAE.

CORYNACTIS AUSTRALIS Haddon and Duerden, 1896.

*Corynactis australis* Haddon and Duerden, 1896, Trans. Roy. Dublin Soc., ser. 2, vi., p. 160.

Associated with growing Hydroids and colonial ascidians. Height of column in largest specimen about 5 mm.; diameter of expanded oral disc 7 mm. Tentacles about 114, conspicuously knobbed, radial arrangement conspicuous, but quite asymmetrical. Reproduction by budding from a common coenenchyme appeared to be taking place and no gonads were found. In general, anatomical and histological details agreed with the description for *C. australis*. The exact disposition of the mesenteries could not be seen, but there were at least 15 perfect pairs. Previously recorded from Port Phillip.

Order MADREPORARIA.

Family ORBICELLIDAE.

A small bleached fragment of a colonial coral was found associated with marine organic debris in a joint plane at the top of McCoy Platform. It is definitely an orbicellid type, but the genus is not determinable.



## 12. Echinodermata.

By LEO. W. STACH, B.Sc.

All the forms listed below were collected from the rock pools at Dinghy Cove, except *Goniocidaris geranioides tubaria* and *Astroconus australis* which were obtained from 25 fathoms off West Cape.

## Class ASTEROIDEA.

## Order PHANEROZONIA.

## Family GONIASTERIDAE.

*TOSIA AUSTRALIS* Gray, 1840.

*Tosia australis* Gray, 1840, Ann. Mag. Nat. Hist., ser. 1, vi, p. 281.

Clark, 1928, Rec. South Aust. Mus., iii. (4), p. 381.

Several specimens of the variation described as "var. *astrologorum* (Muller and Troschel, 1842)" were found occurring with the more numerous typical forms.

## Order SPINULOSA.

## Family ASTERINIDAE.

## ASTERINA (ASTERINA) SCOBINATA Livingstone, 1933.

*Asterina scobinata* Livingstone, 1933, Rec. Aust. Mus., xix. (1). p. 1, pl. v., figs. 9-12, 15.

The three specimens of this form previously known bear the vague locality, "Tasmania." Two specimens were taken from under stones in the rock pools at Dinghy Cove. It also occurs rarely under rocks on Point Leo reef, Shoreham, Western Port (Stach coll.), while specimens at the National Museum are from Port Albert.

## ASTERINA (PATIRIELLA) CALCAR (Lamarck, 1816).

*Asterias calcar* Lamarck, 1816, Anim. sans Vert., ii., p. 557.

*Patiriella calcar* (Lamarck), Clark, 1928, loc. cit., p. 391.

The blue-green tints of this form were much deeper than is usual with mainland specimens. Livingstone is followed in placing *Patiriella* as a subgenus of *Asterina*.

## ASTERINA (PATIRIELLA) EXIGUA (Lamarck, 1816).

*Asterias exigua* Lamarck, 1816, loc. cit., p. 554.

*Patiriella exigua* (Lamarck), Clark, 1928, loc. cit., p. 392.

## Family ASTERIIDAE.

## COSCINASTERIAS CALAMARIA (Gray, 1840).

*Asterias calamaria* Gray, 1840, loc. cit., p. 179.

*Coscinasterias calamaria* (Gray), Clark, 1928, loc. cit., p. 399.

## ALLOSTICHAETER POLYPLAX Verrill, 1914.

*Allostichaster polyplax* Verrill, 1914, Harriman Alaska Exped., Starfishes, p. 363.

Class OPHIUROIDEA.

Order PHRYNOPHIURIDA.

Family GORGONOCEPHALIDAE.

ASTROCONUS AUSTRALIS (Verrill, 1876).

*Astrophyton australe* Verrill, 1876, Bull. U.S. Nat. Mus., iii., p. 74.

*Astroconus australis* (Verrill), Clark, 1928, *loc. cit.*, p. 419.

This common deep water form was found with the arms entwined about a fragment of sponge. Other records of the same mode of occurrence indicate that this is apparently the normal method of feeding.

Order CHILOPHIURIDA.

Family OPHIOCHITONIDAE.

OPHIONEREIS SCHAYERI (Muller and Troschel, 1844).

*Ophiopsis schayeri* Muller and Troschel, 1844, Arch. für Naturg., x., p. 182.

*Ophionereis schayeri* (M. and T.), Clark, 1928, *loc. cit.*, p. 435.

Class ECHINOIDEA.

Order CIDAROIDA.

Family CIDARIDAE.

GONIOCIDARIS GERANIOIDES TUBARIA (Lamarck, 1816).

*Cidarites tubaria* Lamarck, 1816, *loc. cit.*, p. 57.

*Goniocidaris geranioides tubaria* (Lamarck), Clark, 1928, *loc. cit.*, p. 455.

Order CENTRECHINOIDA.

Family STRONGYLOCENTROTIDAE.

HELIOCIDARIS ERYTHROGRAMMUS (Valenciennes, 1846).

*Echinus erythrogrammus* Valenciennes, 1846, Voy. "Venus," Zooph., pl. vii., fig. 1.

*Heliocidaris erythrogrammus* (Val.), Clark, 1928, *loc. cit.*, p. 468.

13. *Bryozoa*.

By LEO. W. STACH, B.Sc.

The material examined was derived from three *in situ* faunules, viz., from 25 fathoms off West Cape (3), from the rock pool behind the landing platform at Dinghy Cove (5) and from kelp roots at 6 fathoms in Dinghy Cove (7). Some species from the rock pools on the north coast of West Cape (6) are of drift origin. Drift material was obtained from red algae washed up at Dinghy Cove (1), among pebbles and basalt sand west of Dinghy Cove (4) and from the joint planes in the basalt of McCoy Platform (2). This latter source yielded a prolific collection practically duplicating faunule 3, storm waves being responsible for its present position. The rock pool communities are markedly distinct from the deeper water facies, the former being characterized here by the small number of species, predominance of petraliform zoaria, rare reteporiform and stunted catenicelliform elements, while the deeper water facies (3) is characterized by dominant catenicelliform and cellariform zoaria with lesser membraniporiform, reteporiform and flustriform elements (*vide* Stach, 1936, Journ. Geol., xlv. (1), pp. 60-65). The seventy-seven species recorded are typical of the Bass Strait region.

## Sub-phylum ENTOPROCTA.

## Family PEDICELLINIDAE.

PEDICELLINA WHITELEGGEI Johnston and Walker, 1917.

*Pedicellina whiteleggei* Johnston and Walker, 1917, Proc. Roy. Soc. Queensland, xxix. (5), p. 60, fig. 14.

Neither of the two calyces collected from a serpulid substratum at Loc. 6 bear spines, but the spines of the peduncle and all other characters agree with topotypes in the collection of Prof. Harvey Johnston. The discrepancy is in accord with the variation described for *P. cernua* (Pallas) by Osburn (Bull. U.S. Bureau Fish., xxx., p. 213).

## Sub-phylum ECTOPROCTA.

## Class STENOLAEMATA.

## Order CAMPTOSTEGA.

## Family CRISIIDAE.

BICRISIA BICILIATA (Macgillivray, 1869).

*Crisia biciliata* Macgillivray, 1869, Trans. Proc. Roy. Soc. Vic., ix., p. 141.

Loc. 3.

BICRISIA WARRNAMBOOLENSIS Stach, 1935.

*Bicrisia warrnamboolensis* Stach, 1935, Aust. Zool., viii. (2), p. 143, figs. 1-4.

The stolons of this and the preceding species were attached to a red alga. Loc. 3.

CRISIA ACROPORA Busk, 1852.

*Crisia acropora* Busk, 1852, Voyage of "Rattlesnake," i., p. 351.

The present occurrences suggest a deeper water habitat for this species, but specimens have been collected on reefs in Western Port at low tide. Locs. 1, 2, 3, 6, 7.

CRISIA SETOSA Macgillivray, 1869.

*Crisia acropora* Busk, 1852, Voyage of "Rattlesnake," i., p. 351.

Found as drift material at Loc. 6 and on red alga at Loc. 3.

Order ACAMPTOSTEGA.

Family TUBULIPORIDAE.

IDMONEA AUSTRALIS Macgillivray, 1882.

(Pl. XXII., Fig. 2.)

*Idmonca australis* Macgillivray, 1882, Prod. Zool. Vict., dec. vii., p. 30, pl. lxviii., fig. 2.

The suggestion that *I. australis* is conspecific with *I. atlantica* Forbes is dispelled by comparison of the present material with specimens of *I. atlantica* from Kvacnangsijord, Tromso (Norway) (det. C. Anrivillius) (Pl. XXII., Fig. 1). Dimensions of *I. australis* and *I. atlantica* are respectively:—width of branch 0.75 mm., 0.5 mm.; distance between apertures 0.75, 0.45; diameter of aperture 0.15, 0.09. The zooecial tubes of *I. australis* are more or less parallel with the upper face of the branch, while in *I. atlantica* they are directed nearly at right angles to it. Locs. 2, 3.

IDMONEA RADIANS (Lamarck, 1816).

*Retepora radians* Lamarck, 1816, Hist. Nat. An. sans Vert., ii., p. 183.

*Idmonca radians* (Lamarck), Macgillivray, 1882, loc. cit., p. 30, pl. lxviii., fig. 3.

Locs. 2, 3.

Order PACHYSTEGA.

Family HORNERIDAE.

HORNERA FOLIACEA Macgillivray, 1869.

*Hornera foliacea* Macgillivray, 1869, loc. cit., p. 142. Locs. 2, 3.

HORNERA ROBUSTA Macgillivray, 1883.

*Hornera robusta* Macgillivray, 1883, Trans. Proc. Roy. Soc. Vic., xix., p. 291, pl. i., fig. 1.

Locs. 2, 3.

Order CALYPTROSTEGA.

Family LICHENOPORIDAE.

LICHENOPORA ECHINATA (Macgillivray, 1884).

*Discoporella echinata* Macgillivray, 1884, Trans. Proc. Roy. Soc. Vic., xx., p. 127, fig. 4.

*Lichenopora echinata* (Macgillivray), 1887, Trans. Proc. Roy. Soc. Vic., xxiii., p. 219.

Loc. 3.

Order HETEROPORINA.  
Family HETEROPORIDAE.

DENSIPORA CORRUGATA Macgillivray, 1881.

*Densipora corrugata* Macgillivray, 1881, Trans. Proc. Roy. Soc. Vic., xvii., p. 17, fig. 2. Borg, 1933, Zool. Bidr. Uppsala, xiv., p. 342, pl. xiii., figs. 1-7, text-figs. 21-24.

This species is the major constituent of the epiphytic faunal community of the marine angiosperm, *Cymodocea antarctica* Endlicher, and until now it has been recorded only from this substratum. Locs. 2, 3. At the latter locality specimens occurred on slender cylindrical stems of a brown alga.

Class GYMNOLAEMATA.  
Order CHEILOSTOMATA.  
Suborder ANASCA.  
Family MEMBRANIPORIDAE.

ACANTHODESIA UNCINATA (Macgillivray, 1890).

*Biflustra uncinata* Macgillivray, 1890, Proc. Roy. Soc. Vic., n.s., ii., p. 107, pl. v., fig. 2.

Loc. 2.

Family ELECTRIDAE, nom. mut.

*Electrinidae* d'Orbigny, 1852, Pal. Franc. Terr. Cret., v., p. 329. Canu and Bassler, 1920, U.S. Nat. Mus. Bull., No. 106, p. 73.

Harmer (1926, Repts. "Siboga" Exped., Mon. xxvii. b, p. 206) and Bassler (1935, Foss. Cat., lxvii., p. 102) place *Electrina* d'Orbigny, 1851 in the synonymy of *Electra* Lamouroux, 1816. Consequently the family name must undergo the above change (Art. 5, Intern. Rules Zool. Nomen.).

ELECTRA PILOSA (Linnaeus, 1767).

*Flustra pilosa* Linnaeus, 1767, Syst. Nat., ed. 12, p. 1301.

*Electra pilosa* (Linnaeus), Livingstone, 1929, Vid. Medd. Dansk Naturh. Foren., lxxxvii., p. 51.

Loc. 6.

Family FLUSTRIDAE.  
CARBASEA INDIVISA Busk, 1852.

*Carbasea indivisa* Busk, 1852, Cat. Mar. Poly. Brit. Mus., i., p. 53, pl. lviii., figs. 3, 4.

*Carbasea cyathiformis* Macgillivray, 1860, Trans. Phil. Inst. Vic., iv., p. 97, fig. 2.

Numerous cup-like colonies from Loc. 3 were attached by radicles to *Scuticella margaritacea* (Busk).

SPIRALARIA FLOREA Busk, 1861.

*Spiralaria florea* Busk, 1861, Quart. Journ. Micro. Sci., n.s., i., p. 153.

Loc. 3.



Family HINCKSINIDAE.

HINCKSINA CORBULA (Hincks, 1880).

*Membranipora corbula* Hincks, 1880, Ann. Mag. Nat. Hist., ser. 5, vi., p. 378, pl. xvii., fig. 6.

Encrusting a red alga at Loc. 3.

HINCKSINA SERRATA (Macgillivray, 1869).

*Membranipora serrata* Macgillivray, 1869, loc. cit., p. 131.

The specimens, from Loc. 6, bore ovicells containing larvae

Family AETEIDAE.

AETEA ANGUINA (Linnaeus, 1758).

*Sertularia anguina* Linnaeus, 1758, Syst. Nat., ed. 10, p. 816.

*Aetea anguina* (Linnaeus), Macgillivray, 1887, loc. cit., p. 195.  
Loc. 6.

AETEA DILATATA (Busk, 1851).

*Anguinaria dilatata* Busk, 1851, Ann. Mag. Nat. Hist., ser. 2, vii., p. 85.

*Aetea dilatata* (Busk), Jelly, 1889, Syn. Cat. Rec. Mar. Bryo., p. 4.  
Loc. 3.

Family ARACHNOPUSIIDAE.

ARACHNOPUSIA MONOCEROS (Busk, 1854).

*Lepralia monoceros* Busk, 1854, Cat. Mar. Poly. Brit. Mus., ii., p. 72, pl. xciii., figs. 5, 6.

*Arachnopusia monoceros* (Busk), Livingstone, 1924, Rec. Aust. Mus., xiv. (3), p. 203.

Locs. 2, 3, 4.

ARACHNOPUSIA ACANTHOCEROS (Macgillivray, 1887).

*Cribrilina acanthoceros* Macgillivray, 1887, loc. cit., p. 68, pl. ii., fig. 4.

*Arachnopusia acanthoceros* (Macgillivray), Livingstone, 1924, loc. cit., p. 204.

Locs. 2, 3.

Family MICROPORIDAE.

CALESCHARA DENTICULATA (Macgillivray, 1869).

*Eschara denticulata* Macgillivray, 1869, loc. cit., p. 138.

*Caleschara denticulata* (Macgillivray), Stach, 1935, Proc. Roy. Soc. Vic., n.s., xlvii. (2), p. 340.

Locs. 2, 3.

MICROPORA CORIACEA (Esper, 1791).

*Flustra coriacea* Esper, 1791, Die Pflanzenthier, pl. vii., fig. 2.

*Micropora coriacea* (Esper), Canu and Bassler, 1920, loc. cit., p. 235.

The specimens obtained bore ovicells containing larvae. Loc. 5.

Family STEGANOPORELLIDAE.

STEGANOPORELLA TRUNCATA Harmer, 1900.

*Steganoporella truncata* Harmer, 1900, Quart. Journ. Micro. Sci., xliii., p. 276, pl. xii., fig. 9, pl. xiii., figs. 36, 37.

Loc. 2.

## Family CELLARIIDAE.

## CELLARIA SETIGERA Pergens, 1887.

*Cellaria setigera* Pergens, 1887, Bull. Soc. Roy. Malac. Belge, xxii., p. 89. Stach, 1935, *loc. cit.*, p. 342.  
Locs. 1, 2, 3, 7.

## CELLARIA TENUIROSTRIS (Busk, 1852).

*Salicornaria tenuirostris* Busk, 1852, *loc. cit.*, i., p. 17, pl. lxiii., fig. 4.  
*Cellaria tenuirostris* (Busk), Macgillivray, 1887, *loc. cit.*, p. 201.  
Loc. 3.

## Family SCRUPOCELLARIIDAE.

## BUGULOPSIS CUSPIDATA (Busk, 1852).

*Cellularia cuspidata* Busk, 1852, *loc. cit.*, p. 19, pl. xxvii., figs. 1, 2.  
*Bugulopsis cuspidata* (Busk), Levinsen, 1909. Morph. Syst. Stud. Cheil. Bryo., p. 132.

Attached to red alga at Loc. 3 and to *Vittaticella buskii* (Thomson) at Loc. 7. Also at Loc. 2.

## CABEREA DARWINII Busk, 1884.

*Caberea darwinii* Busk, 1884, Challenger Repts., xxx., p. 29, pl. xxxii., fig. 6. Jelly, 1889, *loc. cit.*, p. 31.  
Locs. 3, 6, 7.

## CABEREA GLABRA Macgillivray, 1886.

*Caberea glabra* Macgillivray, 1886, Trans. Proc. Roy. Soc. Vic., xxii., p. 129.  
Locs. 3, 5.

## CABEREA GRANDIS Hincks, 1881.

*Caberea grandis* Hincks, 1881, Ann. Mag. Nat. Hist., ser. 5, viii., p. 2, pl. iii., fig. 4. Stach, 1935, *loc. cit.*, p. 342, pl. xii., fig. 3.  
Locs. 2, 3.

## EMMA CRYSTALLINA Gray, 1843.

*Emma crystallina* Gray, 1843, in Dieffenbach's "New Zealand," ii., p. 293. Harmer, 1923, Journ. Linn. Soc. Zool., xxxv., p. 357.  
Locs. 2, 3, 5.

## EMMA BUSKII (Thomson, 1858).

*Menipea buskii* Thomson, 1858, *loc. cit.*, p. 144, pl. xii., fig. 1.  
*Emma buskii* (Thomson), Harmer, 1923, *loc. cit.*, p. 357.  
Attached to a red alga and bearing ovicells with larvae at Loc. 3. Also at Locs. 1 and 4.

## EMMA TRICELLATA Busk, 1852.

*Emma tricellata* Busk, 1852, *loc. cit.*, p. 373. Harmer, 1923, *loc. cit.*, p. 357.  
Locs. 3, 6.

## MONARTRON CYATHUS (Thomson, 1858).

*Menipea cyathus* Thomson, 1858, Nat. Hist. Rev., v., p. 143, pl. xv., fig. 10.  
*Monatron cyathus* (Thomson), Canu and Bassler, 1929, U.S. Nat. Mus. Bull., No. 100, ix., p. 224.  
Loc. 1.

SCRUPOCELLARIA CYCLOSTOMA Busk, 1852.

*Scrupocellaria cyclostoma* Busk, 1852, *loc. cit.*, p. 370.  
Locs. 2, 3.

SCRUPOCELLARIA SCRUEA Busk, 1851.

*Scrupocellaria scruea* Busk, 1851, Ann. Mag. Nat. Hist., ser. 2, vii., p. 83, pl. ix., figs. 11, 12.

At Loc. 2 a young colony of five zooecia was found attached to the basal surface of the lateral compartments of a zooecium of *Vittaticella davesoni* (Thomson). The ancestrula, attached by a slender chitinous stalk equal in length to that of a zooecium, is bulbous, the membranous area being surrounded by seven slender hollow outgrowths. A chitinous joint separates the ancestrula from the second, third and succeeding zooecia. Also at Locs. 3, 6.

Family BICELLARIELLIDAE.

CORNUCOPINA GRANDIS (Busk, 1852).

*Bicellaria grandis* Busk, 1852, *loc. cit.*, p. 374.

*Cornucopina grandis* (Busk), Levensen, 1909, *loc. cit.*, p. 110, pl. iv., figs. 5a-c.

Specimens were attached to *Cellaria setigera* Pergens, *Costaticella solida* (Levensen) and to a sponge at Loc. 3.

DIMETOPIA CORNUTA Busk, 1852.

*Dimetopia cornuta* Busk, 1852, *loc. cit.*, p. 384, pl. i., figs. 7, 8.  
Loc. 2.

DIMETOPIA HIRTA Macgillivray, 1886.

*Dimetopia hirta* Macgillivray, 1886, *loc. cit.*, p. 128.  
Loc. 3.

DIMETOPIA BAREATA (Lamouroux, 1816).

*Dynamena barbata* Lamouroux, 1816, Hist. Polyp. Corall. Flex., p. 168.

*Dimetopia spicata* Busk, 1852, *loc. cit.*, p. 384, pl. i., fig. 9. Harmer, 1923, *loc. cit.*, p. 307.

Loc. 2.

Family BEANIIDAE.

BEANIA (DIACHORIS) MAGELLANICA (Busk, 1852).

*Diachoris magellanica* Busk, 1852, *loc. cit.*, p. 54, pl. lxvii.

*Beania magellanica* (Busk), Macgillivray, 1887, *loc. cit.*, p. 203.  
Locs. 5, 7.

BEANIA (DIACHORIS) SPINIGERA (Macgillivray, 1860).

*Diachoris spinigera* Macgillivray, 1860, *loc. cit.*, p. 164.

This form was collected *in situ* at Loc. 6.

Suborder ASCOPHORA.

Family HIPPOTHOIDAE.

HIPPOTHOA DISTANS Macgillivray, 1869.

*Hippothoa distans* Macgillivray, 1869, *loc. cit.*, p. 130.  
Loc. 6.

## Family PETRALIIDAE.

MUCROPETRALIELLA ELLERII (Macgillivray, 1869).

*Lepralia ellerii* Macgillivray, 1869, *loc. cit.*, p. 135.

*Mucropetraliella ellerii* (Macgillivray), Stach, 1936, *Rec. Aust. Mus.*, xix. (6), p. 373, Text-figs. 14a-c.

Loc. 5.

MUCROPETRALIELLA NODULOSA Stach, 1936.

*Mucropetraliella nodulosa* Stach, 1936, *loc. cit.*, p. 377, Text-figs. 18a-b.  
Locs. 2, 6.

## Family SCHIZOPORELLIDAE.

## Subfamily SCHIZOPORELLINAE.

SCHIZOBRACHIELLA MAPLESTONEI (Macgillivray, 1879).

*Schizoporella maplestoni* Macgillivray, 1879, *Prod. Zool. Vic.*, dec. iv, p. 24, pl. xxxv., fig. 7.

This form was bearing ovicells containing larvae at Loc. 6.

SCHIZOMAVELLA LATA (Macgillivray, 1883).

*Schizoporella lata* Macgillivray, 1883, *loc. cit.*, p. 132, pl. i., fig. 7.  
Loc. 6.

SCHIZOPORELLA BITURRITA Hincks, 1884.

*Schizoporella biturrita* Hincks, 1884, *Ann. Mag. Nat. Hist.*, ser. 5, xiv., p. 280.

*Gephyrophora biturrita* (Hincks), Canu and Bassler, 1920, *loc. cit.*, p. 521.

This form has been referred recently to *Gephyrophora* Busk, 1884, because of the form of the oral avicularia which, however, never meet across the aperture to form a spiramen in this species. Its affinities are with Canu and Bassler's group "*Schizopodrella*" (now a synonym of *Schizoporella* Hincks, 1877). Loc. 3.

## Family SMITTINIDAE.

MUCRONELLA DIAPHANA (Macgillivray, 1879).

*Lepralia diaphana* Macgillivray, 1879, *loc. cit.*, p. 22, pl. xxxv., fig. 3.

*Mucronella diaphana* (Macgillivray), 1887, *loc. cit.*, p. 213.

This form was encrusting a laminate calcareous alga at Loc. 3 and bore ovicells containing larvae.

## Family TUBUCELLARIIDAE.

TUBUCELLARIA HIRSUTA (Lamouroux, 1816).

*Cellaria hirsuta* Lamouroux, 1816, *loc. cit.*, p. 126, pl. ii., fig. 4.

*Tubucellaria hirsuta* (Lamouroux), Stach, 1935, *loc. cit.*, p. 344, pl. xii., fig. 6.

Loc. 2.

Family RETEPORIDAE.

IODICTYUM PHOENICEUM (Busk, 1854).

*Retepora phanicea* Busk, 1854, *loc. cit.*, p. 94, pl. cxxi., figs. 1, 2.

*Iodictyum phanicum* (Busk), Stach, 1936, Trans. Roy. Soc. South Aust., ix., p. 130.

Loc. 2.

SCHIZORETEPORA TESSELLATA (Hincks, 1878).

*Retepora tessellata* Hincks, 1878, Ann. Mag. Nat. Hist., ser. 5, i., p. 358, pl. xix., figs. 9-12.

*Schizoretepora tessellata* (Hincks), Harmer, 1933, Proc. Zool. Soc., pt. 3, p. 619.

Loc. 2.

SERTELLA FISSA (Macgillivray, 1869).

*Retepora fissa* Macgillivray, 1869, p. 140.

Loc. 5.

TRIPHYLLOZON MONILIFERUM (Macgillivray, 1860)  
(*sensu stricto*).

*Retepora monilifera* Macgillivray, 1860, *loc. cit.*, p. 168.

*Triphyllozoon moniliferum* (Macgillivray), Canu and Bassler, 1917, U.S. Nat. Mus. Bull., No. 96, p. 56.

Loc. 2.

TRIPHYLLOZON UMBONATUM (Macgillivray, 1884).

*Retepora monilifera* form *umbonata* Macgillivray, 1884, *loc. cit.*, p. 107, pl. iii., fig. 5, pl. i., fig. 5.

*Triphyllozoon cuspidatum* Harmer, 1933, *loc. cit.*, p. 623.

Harmer (1933, p. 623) proposes the new name *Triphyllozoon cuspidatum* in place of *Retepora monilifera* var. *umbonata* Macgillivray, 1884, for no stated reason. Harmer's name is also not available for use in place of *Retepora umbonata* Buchner, 1924 (*non* Macgillivray, 1884) and must pass into the synonymy of *Triphyllozoon umbonatum*. It should also be noted that Art. 35 of the International Rules Zool. Nomen. does not permit the establishment of Harmer's new name, *Triphyllozoon apertum* for *Retepora monilifera* var. *sinuata* which he proposes because of Kirkpatrick's use of *Retepora sinuosa* in 1888. Apart from this, Macgillivray's name must stand since it has undoubted priority over that of Kirkpatrick. Loc. 2.

Family ADEONIDAE.

ADEONA GRISEA Lamouroux, 1821.

*Adeona grisea* Lamouroux, 1821, Expos. Meth. Genres. Polyp., p. 40, pl. lxx., fig. 5.

*Dictyopora grisea* (Lamouroux), Macgillivray, 1882, Prod. Zool. Vic., dec. vii., p. 23. pl. lxvi., fig. 1.

Loc. 3.



## ADEONELLOPSIS AUSTRALIS Macgillivray, 1886.

(Pl. XXII., Fig. 3.)

*Adeonellopsis australis* Macgillivray, 1886, *loc. cit.*, p. 135, pl. ii., figs. 2, 3. Stach, 1936, *loc. cit.*, p. 131, pl. xv., fig. 5.

Loc. 3.

## LAMINOPORA DISPAR (Macgillivray, 1869).

(Pl. XXII., Fig. 4.)

*Eschara dispar* Macgillivray, 1869, *loc. cit.*, p. 138.

Loc. 3.

## Family CELLEPORIDAE.

## CELLEPORA LIRATA Macgillivray, 1888.

*Cellepora lirata* Macgillivray, 1888, *Prod. Zool. Vic.*, dec. xvii., p. 250, pl. clxvii., fig. 3.

Loc. 3.

## CELLEPORA MAGNIROSTRIS Macgillivray, 1888.

*Cellepora magnirostris* Macgillivray, 1888, *loc. cit.*, p. 251, pl. clxvii., fig. 4.

Loc. 3.

## Family CATENICELLIDAE.

## Subfamily VITTATICELLINAE.

## VITTATICELLA BUSKII (Thomson, 1858).

*Catenicella buskii* Thomson, 1858, *loc. cit.*, p. 139, pl. xi., fig. 2.*Vittaticella buskii* (Thomson), Maplestone, 1901, *Proc. Roy. Soc. Vic.*, n.s., xiii. (2), p. 203.

Loc. 7.

## VITTATICELLA CRYSTALLINA (Thomson, 1858).

*Catenicella crystallina* Thomson, 1858, *loc. cit.*, p. 139, pl. xiii., fig. 1.*Vittaticella crystallina* (Thomson), Maplestone, 1901, *loc. cit.*, p. 203.

Loc. 2.

## VITTATICELLA DAWSONI (Thomson, 1858).

*Catenicella dawsoni* Thomson, 1858, *loc. cit.*, p. 138, pl. xi., fig. 1.*Vittaticella dawsoni* (Thomson), Maplestone, 1901, *loc. cit.*, p. 203.

Locs. 2, 3, 6.

## VITTATICELLA ELEGANS (Busk, 1852).

*Catenicella elegans* Busk, 1852, *loc. cit.*, p. 361, pl. i., fig. 2.*Vittaticella elegans* (Busk), Stach, 1934, *Proc. Roy. Soc. Vic.*, n.s., xlvii. (1), p. 19, pl. iii., figs. 1-4.

Specimens from Loc. 3 bore ovicells. Also found at Loc. 7.

## VITTATICELLA FORMOSA (Busk, 1852).

*Catenicella formosa* Busk, 1852, *loc. cit.*, p. 360.*Vittaticella formosa* (Busk), Maplestone, 1901, *loc. cit.*, p. 202.

Loc. 7.

Subfamily SCUTICELLINAE.

SCUTICELLA LORICA (Busk, 1852).

*Catenicella lorica* Busk, 1852, *loc. cit.*, p. 358.

*Scuticella lorica* (Busk), Stach, 1934, *loc. cit.*, p. 23, Text-figs. 1-4.

Loc. 3.

SCUTICELLA MARGARITACEA (Busk, 1852).

*Catenicella margaritacea* Busk, 1852, *loc. cit.*, p. 356.

*Scuticella margaritacea* (Busk), Levinsen, 1909, *loc. cit.*, p. 229.

Specimens from Loc. 3 bore ovicells with larvae. Also found at Locs. 1, 7.

SCUTICELLA PLAGIOSTOMA (Busk, 1852).

*Catenicella plagiotoma* Busk, 1852, *loc. cit.*, p. 358.

*Scuticella plagiotoma* (Busk), Stach, 1934, *loc. cit.*, p. 15. Text-fig. 8.

Loc. 2.

COSTATICELLA HASTATA (Busk, 1852).

*Catenicella hastata* Busk, 1852, *loc. cit.*, p. 355.

*Costaticella hastata* (Busk), Livingstone, 1929, *loc. cit.*, p. 97.

Loc. 2.

COSTATICELLA SOLIDA (Levinsen, 1909).

*Costicella solida* Levinsen, 1909, *loc. cit.*, p. 234, pl. xx. fig 7a, pl. xii., figs. 1h, k.

*Costaticella solida* (Levinsen), Stach, 1934, *loc. cit.*, p. 17, Text-fig. 4.

Specimens from Loc. 3 bore ovicells containing larvae and were attached to a red alga. Also found at Locs. 2, 7.

CALPIDIUM PONDEROSUM (Goldstein, 1880).

*Catenicella ponderosa* Goldstein, 1880, Journ. Micro. Soc. Vic., i. (2, 3), p. 63, pl. v., figs. 1-3.

*Calpidium ponderosum* (Goldstein), Canu and Bassler, 1929, *loc. cit.*, p. 451, Text-figs. 183I-P.

Locs. 2, 3.

CRIBRICELLINA CRIBRARIA (Busk, 1852).

*Catenicella cribraria* Busk, 1852, *loc. cit.*, p. 359.

*Cribricellina cribraria* (Busk), Stach, 1934, *loc. cit.*, p. 42.

Locs. 2, 3.

Subfamily CATENICELLINAE.

CLAVIPORELLA IMPERFORATA Macgillivray, 1887.

*Claviporella imperforata* Macgillivray, 1887, *loc. cit.*, p. 65, pl. i., fig. 3.

Loc. 1.

PTEROCELLA ALATA (Thomson, 1858).

*Catenicella alata* Thomson, 1858, *loc. cit.*, p. 137, pl. xiii., fig. 4.

*Pterocella alata* (Thomson), Stach, 1935, Proc. Roy. Soc. Vic., n.s., xlviii. (1), p. 27.

Loc. 2.

PTEROCELLA GEMELLA (Macgillivray, 1887).

*Catenicella gemella* Macgillivray, 1887, *loc. cit.*, p. 64, pl. i., fig. 1.  
Loc. 2.

Order CTENOSTOMATA.

Family VESICULARIIDAE.

AMATHIA PLUMOSA Macgillivray, 1890.

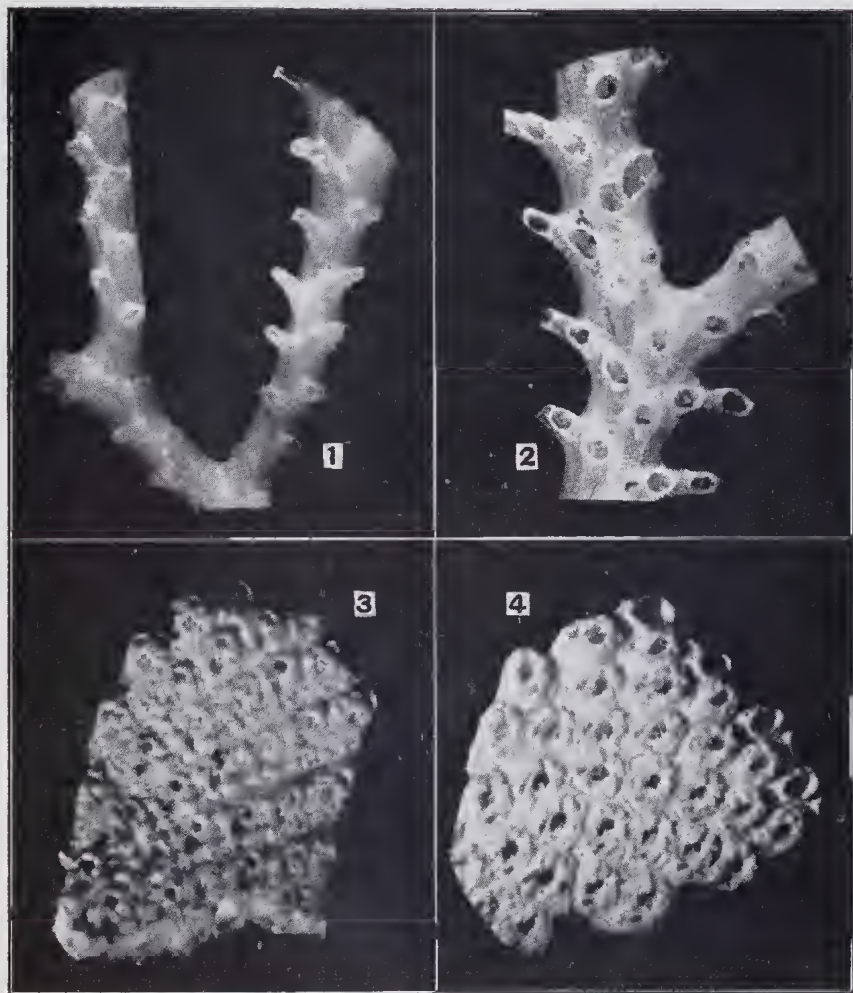
*Amathia plumosa* Macgillivray, 1890, *loc. cit.*, p. 110.  
Locs. 3, 6.

CRYPTOPOLYZOON WILSONI (Dendy, 1889).

*Cryptozoon wilsoni* Dendy, 1889, Proc. Roy. Soc. Vic., n.s., i.  
*Cryptopolyzoon wilsoni* (Dendy), 1900, Zool. Anzeiger, xxiii., p. 391.  
Locs. 3, 7.

### Explanation of Plate XXII.

- Fig. 1.—*Idmonca atlantica* Forbes. Kvaenangsfjord, Tromso (Norway).  
Plesiotype, Nat. Mus. Coll. No. 70072.
- Fig. 2.—*Idmonca australis* Macgillivray. From debris in the joint planes  
of the basalt at McCoy Platform. Plesiotype, Nat. Mus. Coll.  
No. 70073.
- Fig. 3.—*Adeonellopsis australis* Macgillivray. From 25 fathoms off West  
Cape. Plesiotype, Nat. Mus. Coll. No. 70074.
- Fig. 4.—*Laminopora dispar* (Macgillivray). From 25 fathoms off West  
Cape. Plesiotype, Nat. Mus. Coll. No. 70075.



Bryozoa of Lady Julia Percy Island.





14. *Mollusca*.

By F. A. SINGLETON.

Owing to the uniformly rocky nature of the coastline of Lady Julia Percy Island and the heavy seas which sweep it, conditions are unfavourable for molluscs, which are virtually restricted to some of the commoner littoral and sub-littoral gasteropods and a few chitons. The number of species is therefore very limited in comparison with that of the adjacent mainland, but probably further collecting would add to the 46 listed below, which include littoral forms taken alive, and sub-littoral shells washed into rock pools.

Most of the shells are from Dinghy Cove (1), chiefly from the rock pool near the landing, and West Cape (2), from rock pools on the northern side. A few dead shells, cast up by storm waves, were found in crevices on McCoy Platform (3). The only other accessible portions of the coast, from which a few shells were obtained, are at Seal Cave (4) and Pinnacle Point (5), at either end of Seal Bay. In the absence of dredging, the shallow water fauna is represented only by a few shells from off West Cape, in 25 fathoms (6), obtained upon drawing up an anchor.

No land or freshwater shells were found.

I am indebted to Messrs. B. C. Cotton, C. J. Gabriel and G. Mack for assistance with comparative material. The specimens on which the determinations are based have been lodged in the National Museum, Melbourne.

## Class PELECYPODA.

## Family ARCIDAE.

## BARBATIA PISTACHIA (Lamarck, 1819).

*Arca pistachia* Lamarck, Anim. s. Vert., vi., 1819, p. 41.

*Barbatia pistachia* (Lamarck). Gatliff and Gabriel, Proc. Roy. Soc. Vic., n.s., xliii. (2), 1931, p. 230.

Loc. 2, one example.

## Family LIMOPSIDAE.

## LIMOPSIS cf. TENISONI T. Woods, 1878.

*Limopsis tenisoni* Ten. Woods, Pap. Proc. Roy. Soc. Tas., 1877 (1878), p. 56. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xvii. (1), 1904, p. 245. Verco, Trans. Roy. Soc. S. Aust., xxxi., 1907, p. 218.

Loc. 6, one juvenile.

## Family LIMIDAE.

## LIMATULA STRANGEI (Sowerby, 1872).

*Lima strangei* Sowerby, Conch. Icon., xviii., 1872, pl. iii., fig. 15. Hedley, Proc. Linn. Soc. N.S.W., xlviii., 1923, p. 302.

*Lima* (*Limatula*) *bullata* Born. Pritchard and Gatliff, loc. cit., p. 260. Loc. 6, one dead valve.

## Family MYTILIDAE.

## MODIOLUS PULEX Lamarck, 1819.

*Modiola pulex* Lamarck, Anim. s. Vert., vi., 1819, p. 112. Gatliff and Gabriel, Proc. Roy. Soc. Vic., xxx. (1), 1917, p. 30.

Locs. 1, 2, 5, not uncommon.

## Class AMPHINEURA.

## Family ISCHNOCHITONIDAE.

## ISCHNOCHITON ELONGATUS (Blainville, 1825).

*Chiton elongatus* Blainville, Dict. Sci. Nat., xxxvi., 1825, p. 542.

*Ischnochiton crispus* Reeve. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xv. (2), 1903, p. 200.

*Ischnochiton elongatus elongatus*. Iredale and Hull, Monograph Aust. Loricates, 1927, p. 11, pl. i., figs. 1, 1a.

Common under stones in rock pools, Locs. 1 and 2.

## ISCHNOCHITON ATKINSONI Iredale and May, 1916.

*Ischnochiton atkinsoni* Iredale and May, Proc. Mal. Soc. Lond., xii., 1916, p. 110, pl. iv., fig. 3. Gatliff and Gabriel, Proc. Roy. Soc. Vic., xxx. (1), 1917, p. 25. Iredale and Hull, *op. cit.*, p. 20, pl. ii., figs. 3, 3a, b.

With the preceding. Locs. 1 and 2.

## ISCHNORADSIA EVANIDA NOVAEHOLLANDIAE (Reeve, 1847).

*Chiton novae-hollandiae* Reeve, Conch. Icon., iv., 1847, pl. xxi., fig. 142.

*Ischnoradsia evanida novae-hollandiae*, Iredale and Hull, *op. cit.*, p. 35.

*Ischnoradsia australis* (Sowerby). Gatliff and Gabriel (*non* Sowb.), Proc. Roy. Soc. Vic., xliii. (2), 1931, p. 219.

Not definitely localized, but from Loc. 1 or 2.

## Family PLAXIPHORIDAE.

## PONEROPLAX COSTATA (Blainville, 1825).

*Chiton costatus* Blainville, Dict. Sci. Nat., xxxvi., 1825, p. 548.

*Poneroplax costata*. Iredale and Hull, *op. cit.*, p. 100, pl. xii., figs. 1, 9, 10.

*Poneroplax costatus* (Blainville). Gatliff and Gabriel, *loc. cit.*, 1931, p. 225.

On rocks in its usual station between tide marks. Locs. 1 and 2.

## Class GASTEROPODA.

## Family FISSURELLIDAE.

## SCUTUS ANTIPODES Montfort, 1810.

*Scutus antipodes* Montfort, Conch. Syst., ii., 1810, p. 59, pl. xv. Gatliff and Gabriel, Proc. Roy. Soc. Vic., xxxiv., 1922, p. 151.

Two living examples. Loc. 2.

MONTFORTULA RUGOSA (Quoy and Gaimard, 1834).

*Emarginula rugosa* Quoy and Gaimard, *Astrolabe Zool.*, iii., p. 331, pl. lxxviii., figs. 17, 18.

*Subemarginula rugosa* Q. and G. Pritchard and Gatliff, *Proc. Roy. Soc. Vic.*, xv. (2), 1903, p. 187.

*Emarginula (Montfortula) rugosa* Q. and G. Cotton and Godfrey, *S. Aust. Naturalist*, xv. (2), 1934, p. 45, pl. i., fig. 5.

Iredale (*P.L.S.N.S.W.*, xlix. (3), 1924, p. 216) has discussed differences from Peronian shells of Port Fairy examples of this and the preceding species. Locs. 2, 5.

Family HALIOTIDAE.

HALIOTIS (NOTOHALIOTIS) NAEVOSUM Martyn, 1784.

*Haliotis naevosa* Martyn, *Univ. Conch.*, ii., 1784, pl. lxxiii. Pritchard and Gatliff, *loc. cit.*, 1903, p. 178.

*Haliotis (Notohaliotis) naevosa* Martyn. Cotton and Godfrey, *S. Aust. Naturalist*, xv. (1), 1933, pp. 16, 17, pl. i., fig. 4.

Iredale (*loc. cit.*, p. 222) has proposed a subspecies *improbum*, not here adopted, for Port Fairy shells. Loc. 1, common.

Family TROCHIDAE.

CLANCULUS (MESOCLANCULUS) PLEBEJUS (Philippi, 1851).

*Trochus plebejus* Philippi, *Zeit. Malak.*, viii., 1851, p. 41.

*Clanculus plebeius* Philippi. Pritchard and Gatliff, *Proc. Roy. Soc. Vic.*, xiv. (2), 1902, p. 122.

*Mesoclanculus plebejus* (Philippi). Iredale, *Proc. Linn. Soc. N.S.W.*, xlix. (3), 1924, p. 224.

Loc. 1, common under stones.

AUSTROCOCHLEA CONCAMERATA (Wood, 1828).

*Trochus concameratus* Wood, *Index Test.*, suppl., 1828, pl. vi., fig. 35.

*Monodonta concamerata* (Wood). Gatliff and Gabriel, *Proc. Roy. Soc. Vic.*, xliii. (2), 1931, p. 214.

*Austrocochlea concamerata* Wood. Cotton and Godfrey, *S. Aust. Nat.*, xvi. (1), 1934, p. 3, pl. i., fig. 3.

Loc. 1, common.

CHLORODILOMA ADELAIDAE (Philippi, 1849).

*Trochus adelaidae* Philippi, *Conch. Cab.*, ii., 1849, p. 140, pl. xxiv., fig. 1.

*Diloma adelaidae* Philippi. Pritchard and Gatliff, *Proc. Roy. Soc. Vic.*, xiv. (2), 1902, p. 125.

*Austrocochlea (Chlorodiloma) adelaidae* Phil. Cotton and Godfrey, *S. Aust. Nat.*, p. 5, pl. i., fig. 5.

Loc. 1, common.

FOSSARINA PETTERDI CROSSE, 1870.

*Fossarina petterdi* Crosse, *Journ. de Conch.*, 1870, p. 303. Pritchard and Gatliff, *Proc. Roy. Soc. Vic.*, xiv. (2), 1902, p. 49. Cotton and Godfrey, *S. Aust. Nat.*, xvi. (3), 1935, p. 39.

On seaweed in rock pools, Loc. 2.

## Family TURBINIDAE.

## ASTRAEA AUREA (Jonas, 1844).

*Trochus aureus* Jonas, Zeits. Malak., 1844, p. 168.

*Astraliu aureum* Jonas. Pritchard and Gatliff, Proc. Roy. Soc. Vic., 1902, p. 118.

Loc. 1.

## TURBO (LUNELLA) UNDULATUS (Martyn, 1784).

*Limax undulatus* Martyn, Univ. Conch., i., fig. 29.

*Turbo undulatus* Martyn. Pritchard and Gatliff, *loc. cit.*, 1902, p. 114.

Locs. 1 and 2.

## Family ACMAEIDAE.

## PATELLOIDA ALTICOSTATA (Angas, 1865).

*Patella alticostata* Angas, Proc. Zool. Soc. Lond., 1865, p. 56.

*Patelloida (Patelloida) alticostata* (Angas). Oliver, Trans. N.Z. Inst., lvi., 1926, p. 550.

*Patelloida alticostata* (Angas). Gatliff and Gabriel, Proc. Roy. Soc. Vic., xliii. (2), 1931, p. 216.

Much larger and more elevated than Port Phillip examples.  
Locs. 1, 2, 5, common.

## PATELLOIDA (COLLISELLINA) LATISTRIGATA (Angas, 1865).

*Patella latistrigata* Angas, *op. cit.*, p. 154.

*Patelloida (Collisellina) latistrigata* (Angas). Oliver, *loc. cit.*, p. 556.

*Patelloida marmorata* (Tenison-Woods). Gatliff and Gabriel, *loc. cit.*, p. 216.

Locs. 1 and 2.

## NOTOACMEA MAYI (May, 1923).

*Patelloida mayi* May, Illust. Index Tas. Shells, 1923, Appendix, p. 100, for pl. xxii., No. 3, *P. cantharus*, not of Reeve.

*Notoacmea (Notoacmea) mayi* May. Oliver, *loc. cit.*, p. 571.

This is apparently the correct name for the species which appears in the Gatliff collection, now in the National Museum, Melbourne, as *Patelloida cantharus* Reeve. Loc. 2.

## CHIAZACMEA FLAMMEA (Quoy and Gaimard, 1834).

*Patelloida flammea* Quoy and Gaimard, Astrolabe Zool., iii., 1834, p. 354.

*Acmaea flammea* Q. and G. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xv. (2), 1903, p. 196.

*Chiazacmea flammea* Q. and G. Oliver, *loc. cit.*, p. 558.

A tall form which may be included in this variable species.  
Locs. 1 and 2.

## Family PATELLIDAE.

## PATELLA PERONII Blainville, 1825.

*Patella peronii* Blainville, Dict. Sci. Nat., xxxvi., 1825, p. 111. Iredale, Proc. Linn. Soc. N.S.W., xlix. (3), 1924, p. 241.

*Patella ustulata* Reeve. Pritchard and Gatliff, *loc. cit.*, 1903, p. 193.

Locs. 1 and 2, common.

## PATELLA VICTORIANA, sp. nov. (Pl. XXIII., Fig. 1).

*Patella hepatica* Pritchard and Gatliff, *loc. cit.*, 1903, p. 194. Verco, Trans. Roy. Soc. S. Aust., xxx., 1906, p. 207, and xxxi., 1907, p. 99. Iredale, *loc. cit.*, 1924, p. 240.

*Patella victoriae* Gatliff and Gabriel, Proc. Roy. Soc. Vic., xxxiv., 1922, p. 152.

Iredale has pointed out that these two names are technically unavailable for the Victorian shell, which Verco regarded as an extreme variant of *ustulata* Reeve, since their only status is as substitute names for *Acmaea striata* Pilsbry (*non* Quoy and Gaimard), a Celebes shell of different shape.

I therefore describe as a new species a Victorian shell from the Gatliff collection, now in the National Museum, Melbourne.

Holotype.—Shell elongate ovate, moderately elevated, anterior slope 47 deg., posterior slope 26 deg., nearly flat; sculptured by about 100 depressed subequal radiating riblets, increasing by division, crossed by fine lines of growth, interspaces almost linear. Apex subacute, slightly crooked, pointing anteriorly, situate in the anterior third of the shell. Colour dark brown, the interior white to bluish-white, with brown margin.

Length 23.5, breadth 17.7, height 7.7 mm.

Paratype.—This differs in being broader and higher, with the apex nearer the anterior margin; anterior slope 54 deg., posterior slope convex. The better preserved internal margin is weakly denticulated by the termination of the external riblets.

Length 23.7, breadth 18.9, height 8.5 mm.

Holotype and paratype (Reg. Nos. 70,069-70) in the National Museum, Melbourne.

The material available to the writer does not confirm Verco's contention that the shells long known as *hepatica* intergrade with *ustulata* (i.e., *peronii*). Whether the differences are specific or ultimately prove to be subspecific, a distinctive name is desirable for this uniformly sculptured shell, whose brown to greenish brown coloration, usually with a white patch due to apical wear, is characteristic.

In outline it varies from the oblong-oval form noted by Verco, which is that occurring at Lady Julia Percy Island, to a more roundly elliptical form which is commoner in Victoria.

Loc. 2, rare.

## PATELLA (PATELLANAX) SQUAMIFERA Reeve, 1855.

*Patella squamifera* Reeve, Conch. Icon., viii., 1855, pl. xxxii., fig. 94. Gatliff and Gabriel, *op. cit.*, 1922, p. 152. Iredale, *op. cit.*, 1924, p. 239.

Loc. 2.



## CELLANA VARIEGATA (Blainville, 1825).

*Patella variegata* Blainville, Dict. Sci. Nat., xxxviii., 1825, p. 10.*Cellana variegata* Blainville. Gatliff and Gabriel, Proc. Roy. Soc. Vic., 1922, p. 152.*Cellana variegata ariel* Iredale, Proc. Linn. Soc. N.S.W., xlix. (3), 1924, p. 242.

Iredale has noted in a series from Port Fairy two forms: one with flattened ribs, eroded apex and lighter coloration; the other very dark, with sharper cut ribs and little erosion. These were stated to come from sandstone [i.e., dune limestone] and basalt rocks respectively, but the first occurs also on basalt both at Port Fairy and at Lady Julia Percy Island, where it is accompanied by the less common second form.

The distinction between these two forms merits recognition far more than that between the whole Port Fairy series, which Iredale has distinguished subspecifically, and those from Port Phillip Heads easterly, which the writer is unable to separate.

Abundant and of large size. Locs. 1 and 2.

## Family LITTORINIDAE.

## MELARHAPHE UNIFASCIATA (Gray, 1826).

*Littorina unifasciata* Gray, King's Survey Aust., ii., 1827, App., p. 483.*Melarhappe unifasciata* Gray. Gatliff and Gabriel, Proc. Roy. Soc. Vic., xxxiv., 1922, p. 145.

Abundant on rocks, up to 30 feet above high water mark. Locs. 1, 2, 3.

## MELARHAPHE PRAETERMISSA (May, 1909).

*Littorina novaezelandiae* Reeve. Pritchard and Gatliff (*non* Reeve).

Proc. Roy. Soc. Vic., xiv. (2), 1902, p. 91.

*Littorina praetermissa* May, Pap. Roy. Soc. Tas. for 1908, 1909, p. 57, pl. vi., fig. 3.

May's name, given to a Tasmanian shell, is adopted in view of the uncertainty attaching to Reeve's species, which apparently did not come from New Zealand.

Locs. 1, 2, 5, common.

## Family RISSOIDAE.

## RISSOINA ELEGANTULA Angas, 1880.

*Rissoina elegantula* Angas, Proc. Zool. Soc. Lond., 1880, p. 417. pl. xl., fig. 10. Pritchard and Gatliff, *loc. cit.*, 1902, p. 110.

Loc. 6, one example.

## Family CAPULIDAE.

## CAPULUS AUSTRALIS (Lamarck, 1819).

*Patella australis* Lamarck, Anim. s. Vert., vi. (1), 1819, p. 335.*Hipponyx australis* Lamarck. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xii. (2), 1900, p. 198.*Capulus australis* (Lamarck). Iredale, Proc. Linn. Soc. N.S.W., xlix. (3), 1924, p. 245.

Loc. 1, on *Haliotis*.

Family EPITONIIDAE.

OPALIA AUSTRALIS (Lamarck, 1822).

*Scalaria australis* Lamarck, Anim. s. Vert., vi., 1822, p. 228.

*Scala australis* Lamarck. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xiii. (1), 1900, p. 142.

*Opalia australis* Lamarck. Cotton and Godfrey, S. Aust. Nat., xiii. (1), 1931, p. 7, pl. i., fig. 4.

Loc. 1, one dead shell.

Family CYMATIIDAE.

CYMATIELLA VERRUCOSA (Reeve, 1844).

*Triton verrucosus* Reeve, Proc. Zool. Soc. Lond., 1844, p. 118.

*Lotorium verrucosum* Reeve. Pritchard and Gatliff, Proc. Roy. Soc. Vic., x. (2), 1898, p. 266.

*Cymatiella verrucosa* Reeve. Iredale, Rec. Aust. Mus., xvii. (4), 1929, p. 175, pl. xl., fig. 2.

Loc. 3, one example.

Family CYPRAEIDAE.

NOTOCYPRAEA cf. COMPTONII (Gray, 1847).

*Cypraea comptonii* Gray, Jukes' Voy. "Fly," ii., 1847, App., p. 356, pl. i., fig. 3.

*Cypraea angustata* Gmelin, var. *comptoni* Gray. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xii. (2), 1900, pp. 183, 185.

*Notocypraea comptoni* Gray. Cotton and Godfrey, S. Aust. Nat., xiii. (2), 1932, p. 42. Iredale, Aust. Zool., viii. (2), 1935, p. 134.

This is the form usually listed as *comptoni*, but Iredale has shown its applicability to Southern Australian shells to be doubtful.

Loc. 1, one dead shell. Loc. 2, two living examples.

NOTOCYPRAEA VERCONIS Cotton and Godfrey, 1932.

*Cypraea angustata* Gmelin. Pritchard and Gatliff (*non* Gmel.), *loc. cit.*, 1900, p. 183.

*Notocypraea verconis* Cotton and Godfrey, *loc. cit.*, 1932, p. 41, pl. i., fig. 8.

Loc. 1, one dead shell.

Family MARGINELLIDAE.

MARGINELLA (GLABELLA) PYGMAEOIDES, sp. nov. (Plate XXIII., Fig. 2).

"*Marginella pygmaca* Sowerby." Pritchard and Gatliff, *op. cit.*, xi. (2), 1898, p. 191. May., Ill. Ind. Tas. Shells, 1923, pl. xxxi., fig. 9. Not *M. pygmaca* Sowerby, Thes. Conch., i., 1846, p. 386, pl. lxxv., figs. 78, 79.

*Marginella* (*Glabella*) aff. *pygmaca*. Powell, Trans. N.Z. Inst., lxii., 1932, p. 205, pl. xxxiv., fig. 19.

Holotype.—Shell small, solid, volutiform, smooth except for faint growth lines, shining, creamy white. Spire low, about a quarter length of aperture, bluntly conical, spire angle about 72 deg. Protoconch broadly convex, smooth. Whorls 4, sutures

indistinct, spire whorls slightly convex, body whorl large, moderately convex, narrowed anteriorly. Aperture long, channelled and slightly bent posteriorly, widening anteriorly. Outer lip thickened, interior smooth, exterior with a weak varix. Columella oblique, nearly straight, with 4 prominent subequidistant and closely spaced plaits; the three lower stout, oblique, the uppermost thinner and more transverse, at little more than a third the height of the body whorl.

Height 8.5 mm., diameter 5.0 mm.

Port Phillip, Victoria. Gatliff Collection, National Museum, Melbourne, Reg. No. 70071.

The credit for the recognition of the distinction between New Zealand *pygmaea* and Tasmanian shells ascribed to Sowerby's species belongs to Powell, who (*loc. cit.*) has figured shells from both countries and remarked "Tasmanian shells ascribed to *pygmaea* differ from the here assumed typical New Zealand species in having stronger and more closely spaced plaits, the uppermost situated proportionately lower in relation to the height of the body-whorl. The spire also is less blunt, and the labial varix not so high," but refrained from naming the Tasmanian form, since he had not access to Sowerby's original figure, which, as he surmised, represents the New Zealand species.

Powell has recorded a sinistral example from Swansea, Tasmania: another, from Portsea, Victoria, is in the Gatliff Collection.

*M. pygmaeoides* is apparently confined to Tasmania, where it is widespread, and Victoria, whence Pritchard and Gatliff have recorded it (as *pygmaea*) from Port Phillip and Western Port and from Portland (one example).

Loc. 3, one example.

#### Family CANCELLARIIDAE.

##### CANCELLARIA LACTEA Deshayes, 1832.

*Cancellaria lactea* Deshayes, Encyc. Meth., iii., 1832, p. 180.

*Cancellaria laevigata* Sowerby. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xi. (2), 1899, p. 205.

Loc. 1, one dead shell.

#### Family CONIDAE.

##### CONUS (FLORACONUS) ANEMONE Lamarck, 1810.

*Conus anemone* Lamarck, Ann. du Mus., xv., 1810, p. 272. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xii. (2), 1900, p. 180.

*Floraconus anemone* Lamarck. Cotton and Godfrey, S. Aust. Nat., xiii. (2), 1932, p. 68, pl. iii., fig. 12.

Loc. 2, alive. Loc. 3, dead shells.

#### Family FASCIOLARIIDAE.

##### FASCIOLARIA (PLEUROPLOCA) AUSTRALASIA CORONATA Lamarck, 1822.

*Fasciolaria coronata* Lamarck, Anim. s. Vert., vii., 1822, p. 120.

Pritchard and Gatliff, Proc. Roy. Soc. Vic., x. (2), 1898, p. 271.

Loc. 2, badly worn shells.

Family BUCCINIDAE.

COMINELLA LINEOLATA Lamarck, 1809.

*Buccinum lineolatum* Lamarck, Encyc. Meth., i., 1809, pl. 400, fig. 8.  
*Cominella lineolata* Lamarck. Pritchard and Gatliff, *loc. cit.*, 1898,  
 p. 275.

Loc. 1, abundant.

Family COLUBRARIIDAE.

COLUBRARIA RETICULATA (A. Adams, 1854).

*Pisania reticulata* A. Adams, Proc. Zool. Soc. Lond., 1854, p. 138.  
 Pritchard and Gatliff, *loc. cit.*, 1898, p. 274.

*Fusus mestayerae* Iredale, Trans. N.Z. Inst., xlvii., 1915, p. 466. Gatliff  
 and Gabriel, Proc. Roy. Soc. Vic., xxxiv., 1922, p. 132.

*Colubraria reticulata* A. Ad. Cotton and Godfrey, S. Aust. Nat., xvi.  
 (2), 1935, p. 24.

Loc. 1, one dead shell.

Family PYRENIDAE.

PYRENE SEMICONVEXA (Lamarck, 1822).

*Buccinum semiconvexum* Lamarck, Anim. s. Vert., vii., 1822, p. 272.

*Columbella semiconvexa* Lamarck. Pritchard and Gatliff, Proc. Roy.  
 Soc. Vic., xi. (2), 1899, p. 197.

*Pyrene semiconvexa* Lamarck. Cotton and Godfrey, S. Aust. Nat.,  
 xiii. (3), 1932, p. 102, pl. i., fig. 8.

Loc. 3, one example.

Family THAIDIDAE.

NEOTHAIS TEXTILIOSA (Lamarck, 1822).

*Purpura textilis* Lamarck, *loc. cit.*, 1822, p. 77.

*Neothais textilis* Lamarck. Cotton and Godfrey, S. Aust. Nat., xiii.  
 (4), 1932, p. 142, pl. i., fig. 14.

Pritchard and Gatliff (P.R.S.Vic., x. (2), 1898, p. 258) in-  
 cluded this with the Peronian *P. succincta* Martyn.

Locs. 1 and 2, abundant.

LEPSITHAIS VINOSA AUREA (Hedley, 1915).

*Kalydon vinosus* Lamarck, var. *aurea* Hedley, Proc. Linn. Soc. N.S.W.,  
 xxxix. (4), 1915, p. 748.

*Lepsiella vinosa* Lamarck. Gatliff and Gabriel, Proc. Roy. Soc. Vic.,  
 xxxiv., 1922, p. 131 (in part).

*Lepsiithais vinosa* Lamarck. Cotton and Godfrey, S. Aust. Nat., 1932,  
 p. 144 (in part).

Locs. 1 and 2.

Family ELLOBIIDAE.

MARINULA XANTHOSTOMA H. and A. Adams, 1854.

*Marinula xanthostoma* H. and A. Adams, Proc. Zool. Soc. Lond., 1854,  
 p. 35. Cotton and Godfrey, S. Aust. Nat., xiii. (4), 1932, p. 147,  
 pl. iii., fig. 1.

*Marinula patula* Lowe. Gatliff (*non* Lowe), Vic. Nat., xxii. (1), 1905,  
 p. 16.

Loc. 4, one example.

## Family SIPHONARIIDAE.

SIPHONARIA DIEMENENSIS Quoy and Gaimard, 1833.

*Siphonaria diemenensis* Quoy and Gaimard, Astrolabe Zool., ii., 1833, p. 327, pl. xxv., figs. 1-12. Pritchard and Gatliff, Proc. Roy. Soc. Vic., xv. (2), 1903, p. 220.

Locs. 1, 2, 5, common near high tide mark.

SIPHONARIA TASMANICA T. Woods, 1877.

*Siphonaria denticulata* var. *tasmanica* Tenison Woods, Pap. Roy. Soc. Tas. for 1876-1877, p. 54.

*Siphonaria zonata* T. Woods. Pritchard and Gatliff, *loc. cit.*, p. 221.

The interior is darker than is usual in this species. Loc. 2, less common than the preceding.

## Family TETHYIDAE.

TETHYS NORFOLKENSIS (Sowerby, 1869).

*Aplysia norfolkensis* Sowerby, Conch. Icon., xvii., 1869, pl. x, fig. 42.

*Tethys norfolkensis* Sowerby. Hedley, Proc. Linn. Soc. N.S.W., xxx. (4), 1906, p. 536, pl. xxiii., figs. 33, 34 (animal). Cotton and Godfrey, S. Aust. Nat., xiv. (3), 1933, p. 96, pl. i., fig. 21 (shell).

Loc. 2, alive in rock pools.

## Explanation of Plate XXIII.

Fig. 1. *Patella victoriana*, sp. nov. Holotype. Victoria. Nat. Mus., Melb., Reg. No. 70,069.

Fig. 2 a, b. *Marginella pygmaeoides*, sp. nov. Holotype. Port Phillip, Victoria. Nat. Mus., Melb., Reg. No. 70071.



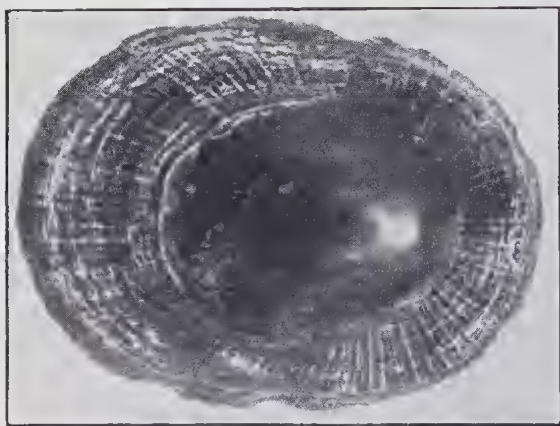


FIG. 1.

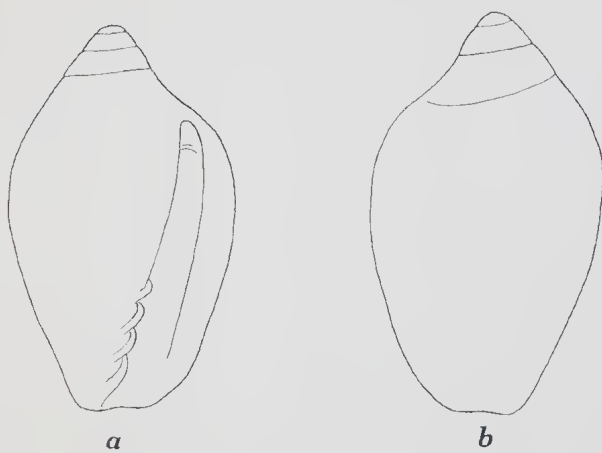


FIG. 2.



15. *Insecta*.

By A. DUNBAVIN BUTCHER.

Family BLATTIDAE.

*Onicosoma granicollis* Sauss.

*Calolampa irrorata* Fabricius.

*Platyzostera* sp.

Family OLIGOTOMIDAE.

*Oligotoma gurneyi* Froggatt

Family LYGAEIDAE.

*Nysius vinitor* Bergroth.

Family MEMBRACIDAE.

*Acanthucius gracilispinus* Stahl.

Family TENEBRIONIDAE.

*Saragus infelix* Pascoe.

Family SCARABAEIDAE.

*Aphodius howitti* Hope.

*Phyllotocus bimaculatus* Erichson.

*Cheiroplatys modelius* Erichson.

Family LAMPYRIDAE.

*Calachromus insidiator* Fairmaire.

Family OEDIMERIDAE.

*Copidita puncta* McLeay.

Family COCCINELLIDAE.

*Coccinella transversalis* Fabricius.

Family BYRRHIDAE.

*Microchaetes sphaericus* Hope.

Family PTINIDAE.

*Ptinus exulans* Erichson.

Family SPHECIDAE.

*Ammophila suspiciosa* Smith.

Family FORMICIDAE.

*Pheidole gellibrandi* Clark.

*Monomorium* (*Notomyrmex*) *rubriceps* var.  
*cincta* Wheeler.

*Iridomyrmex bicknelli* Emery.

*Iridomyrmex punctatissima* Emery.

*Iridomyrmex vicina* Clark.

## Family CALLIPHORIDAE.

*Calliphora* (?) *stygia* Fabricius.*Calliphora* sp.*Chrysomia* sp.

## Family MUSCIDAE.

*Musca* (?) *domestica* Linnaeus.

## Family NOCTUIDAE.

*Peripyræ sanguinipuncta* (Guenée).*Agrotis spina* Guenée.*Euxoa porphyricollis* Guenée.*Euxoa radians* Guenée.*Proteuxoa aspersa* Walker.*Proteuxoa mundoides* Lower.*Idiodes apicata* Guenée.*Siderides unipuncta* (Haworth).*Plusia argentifera* Guenée.

## Family GEOMETRIDAE.

*Euchoeca rubropunctaria* (Doubleday).*Xanthorhoe subochraria* (Doubleday).*Xanthorhoe subidaria* (Guenée).

## Family TORTRICIDAE.

*Tortrix postvittana* (Walker).*Nyctemera annulata* (Boisduval).

## Family NYMPHALIDAE.

*Heteronympha merope* Fabricius.*Pyraus cardui kershawi* McCoy.

Representatives of the following families also were found:—

PHASMIDAE; GRILLIDAE; ACRIDIDAE (*Paragrillacris* sp.); LABIDURIDAE; REDUVIIDAE; COCCIDAE (*Mytilaspis* sp.); CURCULIONIDAE (*Storcus* sp.); BRACONIDAE; CHALCIDAE; ENCYRTIDAE; PSAMMODONTIDAE (*Pseudogenia* sp.); ANDRENIDAE (*Nomia* sp.); HIPPOBOSCIDAE; CHLOROPIDAE (*Parahippites* sp.); NEOTTIOPHILIDAE (*Tapogaster* sp.); BOMBYLIDAE (*Pilla* sp.); CULICIDAE (*Aedes* (*Ocklerolatus*) sp.).

Thanks are due to J. Clark, National Museum, Melbourne, for identifying the Formicidae; to H. F. Consett Davis, Sydney University, for identifying the Embiaria, and to F. H. Taylor, School of Public Health and Tropical Medicine, Sydney, for determining the Diptera.

16. *Cestoda*.

By F. H. DRUMMOND.

The collection of cestodes was small, only five species being represented. Of these, two have not been described previously, and another is also new, but lack of material has rendered an adequate description impossible.

## Order TETRAPHYLLIDEA.

## Family PHYLLOBOTHRIIDAE.

## PHYLLOBOTHRIUM MUSTELI (van Beneden, 1850).

*Anthobothrium musteli* van Beneden, 1850, Mem. Acad. Roy. Sci. Belg., xxv., p. 126, pl. v.

*Phyllobothrium musteli* (van Beneden), Southwell, 1925, Mem. Liverpool School Trop. Med., n.s., ii., p. 173.

Numerous specimens were taken from the spiral valve of a gummy shark (*Mustelus antarcticus*). This cestode has been fully described by Yoshida (1917, Parasitology, ix.).

## PHYLLOBOTHRIUM THRIDAX (van Beneden, 1850).

*Phyllobothrium thridax* van Beneden, 1850, loc. cit., p. 122, pl. v.

*Phyllobothrium thridax* (van Beneden), Southwell, 1925, loc. cit., p. 154.

The material consisted of a single specimen from the spiral valve of a Port Jackson shark (*Heterodontus philippi*).

## Family ONCHOBOTHRIIDAE.

## ACANTHOBOTHRIUM HETERODONTI, n. sp.

(Plate XXIV., Figs. 1-3.)

The description of this species is based on two specimens found in the spiral valve of *Heterodontus philippi*.

External features.—The longer of the two specimens measured 34 cm. mounted in balsam. The segments number several hundred, and posteriorly attain a length of 2.7 mm. and a breadth of 2.0 mm. The last segments were not gravid. The lateral genital pores are irregularly alternate, and slightly posterior to the middle of the segment.

The four bothridia are each divided into three loculi. The total length of a bothridium is 1.2 mm., the anterior loculus measuring 0.6 mm. and the other two about 0.3 mm. each. In front of each bothridium there is a pair of bifurcated hooks. The longer inner prong, which has a tubercle at its base, has a total length of 0.3 mm. and the outer prong measures 0.25 mm. (Fig. 1). Just anterior to the base of the hooks there is an accessory sucker. The bothridia are fused to the head down to the level of the middle loculus.



Internal anatomy.—The testes first appear about six centimetres behind the scolex. When fully developed they number 120-150 and measure  $120\mu$  in diameter. They are situated in the dorsal part of the medulla between the right and left excretory canals. The cirrus sac extends slightly over one-fifth of the breadth of the segment and contains the coiled cirrus and the terminal coiled portion of the vas deferens. In immature segments the vas deferens is a narrow straight tube, but in mature segments it is wider and much coiled in the central part of the anterior half of the segment. The ovaries form a U-shaped mass with the lateral arms extending forward to the level of the cirrus sac and posteriorly meeting behind the shell gland. In transverse sections the ovaries consist of a horizontal layer with dorsal and ventral finger-like extensions. In mature segments the ovarian isthmus is swollen with ova and presses forward against the posterior wall of the uterus. The vagina, which opens to the genital pore just in front of the cirrus, runs back dorsally to the uterus, turns ventrally round the ovarian isthmus and meets the oviduct below the shell gland. From the gland, the uterine duct runs forward to open to the uterus about the level of the genital pore. The uterus is a large sacculated organ in the hindmost segments. There is no uterine pore but the musculature of the body wall is weakened at numerous points along the mid-ventral line. The vitelline glands are marginal in the medulla external to the excretory canals and extend from the level of the shell gland to the anterior end of the segment. The vitelline ducts unite before entering the shell gland. There is a pair of excretory canals on each side. Anteriorly they are approximately equal in diameter, but in the hinder part of the strobila the ventral canals enlarge and have a diameter of more than ten times that of the reduced dorsal canals. The nerve cord runs down at the lateral edge of the medulla. It passes dorsally to the cirrus and vagina.

The present species appears to be closely related to *Acanthobothrium cestraciontis*, Yamaguti (1934, Jap. Jour. Zool., vi., pt. 1). The presence of accessory suckers in *A. heterodonti* and their absence in *A. cestraciontis* is possibly of little significance, but the two species can be distinguished by the character of the hooks and by several features of the reproductive organs.

#### PLATYBOTHRIUM sp.

A single immature specimen of a *Platybothrium* was found in the spiral valve of *Mustelus antarcticus*. The scolex shows the flattening characteristic of the genus, but the hooks are distinctive in that, in each pair, both hooks are bifurcated. This feature is sufficient to distinguish the species from the two previously described species recorded by Southwell (1925), but it is considered inadvisable to describe a new species from such scanty material.

## Order PSEUDOPHYLLIDEA.

## Family DIPHYLLOBOTHRIDAE.

## DIPHYLLOBOTHRUM ARCTOCEPHALI, n. sp.

(Plate XXIV., Figs. 4, 5.)

One mature specimen and a number of immature specimens were found in the caecum and colon of a seal, *Arctocephalus tasmanicus*.

The large specimen measured 23 cms. in length and attained a maximum width of 0.6 cm. The anterior segments are 3-4 mms. wide but extremely short, measuring only 0.03 mm. The segments gradually increase in length, and at the widest part of the strobila about 17 cms. behind the scolex, are 3 mms. long. Posteriorly to this region the segments become square and the terminal ones are longer than broad. They measure 6 mms. long by 3 mms. wide. The segments overlap slightly at the posterior margin.

The scolex is small, somewhat expanded towards the tip particularly in the dorso-ventral plane. In end view it is more or less rectangular, slightly longer dorso-ventrally than from side to side. The scolex has a length of 1.0 mm. and a maximum width of 0.9 mm. The bothridia which are on the dorsal and ventral surfaces extend forward to the apex of the head where they attain their maximum width of 0.8 mm. Posteriorly the two lips of a bothridium come together at a point half way down the scolex, and the sucker is continued as a narrow cleft to the base of the scolex. The lips are thin and are not folded (Fig. 2). The anterior border has a median notch and between the notches in the two bothridia the scolex forms a short conical restellum.

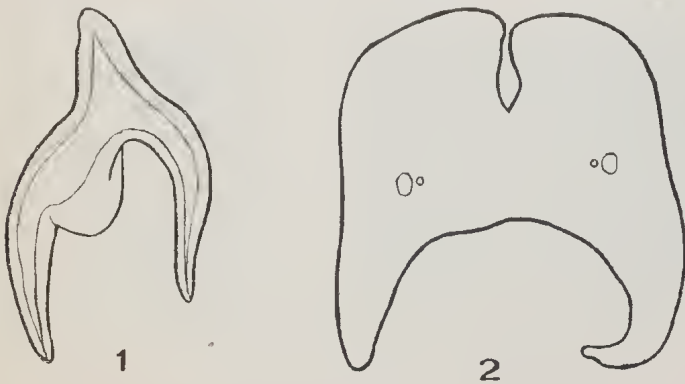


Fig. 1.—Hook from bothridium of *Acanthobothrium heterodonti*, n. sp. (x. 75.)

Fig. 2.—Transverse section of the scolex of *Diphyllobothrium arctocephali*, n. sp. (x. 20.)

There is no neck; segmentation begins immediately behind the scolex.

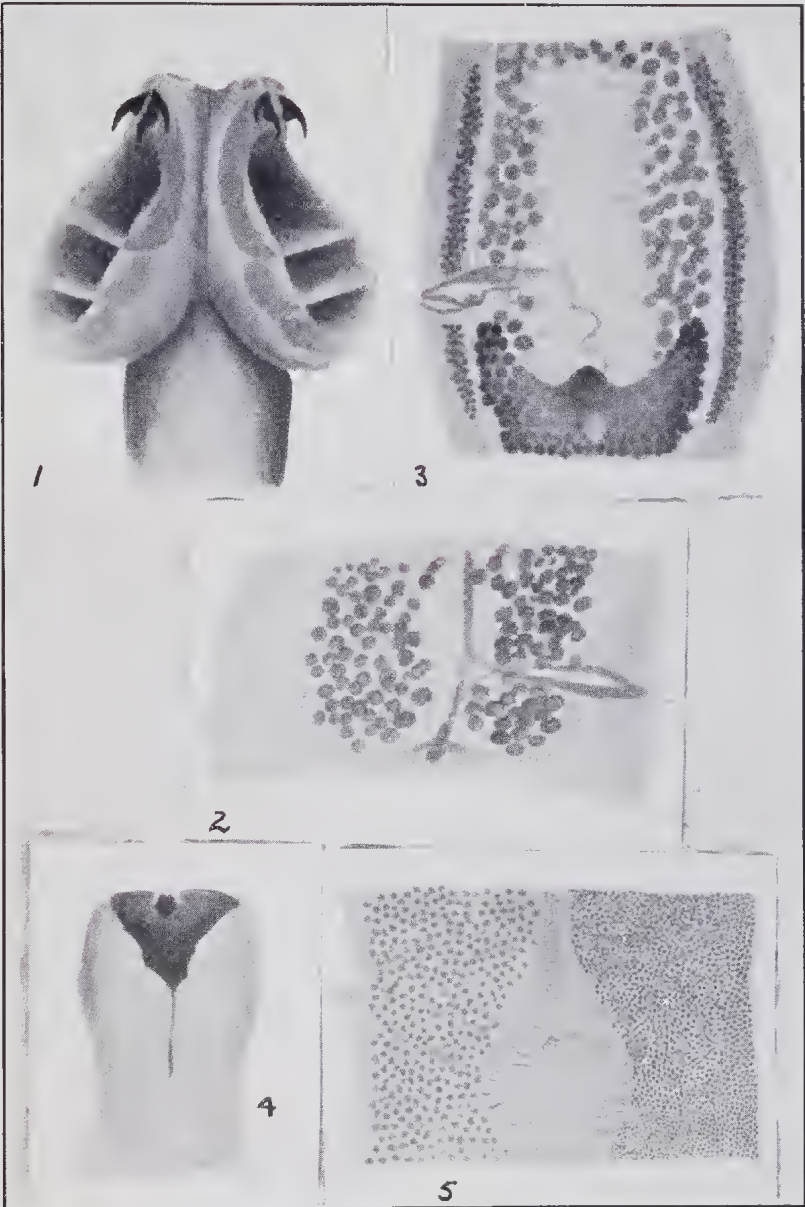
Rudiments of the genitalia appear about 6 mms. behind the scolex. The genital pore which has a diameter of  $75\mu$  is approximately half way along the segment and the uterine opening is a little distance further back. Both openings are situated in a median longitudinal groove continuous from segment to segment. Anterior to the genital pore the cuticle lining the groove shows a series of small puckering. The testes are distributed over the full length of the segment in two lateral fields, separated posteriorly by the uterus, and anteriorly by a narrow area which is also devoid of vitelline gland follicles. In transverse sections 10-15 testes appear on each side. The uterus is a coiled tube with from 9-12 loops on each side. It forms a rosette shaped mass in the posterior half of the segment. The eggs are oval and operculated. They measure  $60\mu \times 35\mu$ .

The longitudinal nerve cords are situated about one-quarter of the width of the segment from the margin. The excretory vessels are slightly more median. The muscular system is typical.

### Explanation of Plate.

1. Scolex of *Acanthobothrium heterodonti*, n. sp. ( $\times 24$ .)
2. Immature proglottis of *A. heterodonti*, n. sp. ( $\times 40$ .)
3. Mature proglottis of *A. heterodonti*, n. sp. ( $\times 24$ .)
4. Scolex of *Diphyllobothrium arctocephali*, n. sp. ( $\times 20$ .)
5. Mature proglottid of *D. arctocephali*, n. sp. ( $\times 12$ .)

The testes are shown on the left hand and the vitellaria on the right.



Two new Species of Cestoda.





17. *Nemertini*.

By J. A. TUBB, B.Sc.

Family CEREBRATULIDAE.

LINEUS VITTATUS (Quoy and Gaimard, 1833).

*Borlasia vittata* Quoy and Gaimard, 1833, Voy. Astrolabe, iv., p. 287.

*Lineus vittatus* (Quoy and Gaimard), Bürger, 1904, Das Tierreich, xx., p. 94.

A specimen was taken in a rock pool on Square Reef, others being observed in the rock pools of Dinghy Cove.

LINEUS sp.

A small, probably regenerating, fragment of a form seen in the rock pools of Dinghy Cove has affinities with *Lineus anas* Joubert and Francois. The specimen (8 mm. long, 1 mm. in diameter) is black with twelve narrow white rings. The head elefts are bordered with white, but neither eyespots nor proboscis can be demonstrated.

## 18. Crustacea.

By J. A. TUBB.

## Class CIRRIPIEDIA.

## Family CHTHALAMIDAE.

CATAPHRAGMUS POLYMERUS Darwin, 1853.

*C. polymerus* Darwin, 1853, Monograph of the Cirripedia, Balanidae. Ray. Soc. Publ. London, p. 487.

CHAMAESIPHO COLUMNA (Spengler, 1790).

*Lepas columna* Spengler, 1790, Skrifter Natur. hist., Selskabet, i. Pl. vi.*C. columna* Darwin, 1853, *l.c.*, p. 471.

## Family BALANIDAE.

TETRACLITA PURPURASCENS (Wood, 1815).

*Lepas purpurascens* Wood, 1815, General Conchology, p. 58.*T. purpurascens* Darwin, 1853, *l.c.*, p. 337.

These three species were extremely common along most of the coastline of the Island, particularly at West Cape, on the rocks of which barnacles (most commonly *T. purpurascens*) were found as high as 35 feet above water level, but were wetted by spray at high tide.

## Class DECAPODA.

## Family PALAEMONIDAE.

LEANDER SERENUS Heller, 1865.

*L. serenus* Heller, 1865, Reise der Novara, Crustacea, p. 110.

Fairly common in rock pools along the western coast.

## Family SYNALPHEIDAE.

CRANGON SOCIALIS (Heller, 1865).

*Alpheus socialis* Heller, 1865, *loc. cit.*, p. 106.*C. socialis* Hale, 1924, Crustacea of South Australia, p. 46.

Only one specimen was taken, but several of these forms were heard "snapping" in rock crevices in Dinghy Cove.

## Family PALINURIDAE.

JASUS LALANDII (Lamarck).

*Palinurus lalandii* Lamarck, MS., in Museum, Jardin des Plantes.*J. lalandii* Hale, 1929, *l.c.*, p. 65.

This species was commonly taken in 3-4 fathoms off Dinghy Cove.

## Family PORCELLANIDAE.

PETROCHELES AUSTRALIENSIS Miers, 1876.

*P. australiensis* Miers, 1876, *Cat. Crust. N.Z.*, p. 91.

One specimen taken, and several observed among the rocks in Dinghy Cove.

Family LITHODIIDAE.

LOMIS HIRTA (Lamarck, 1816).

*Porcellana hirta* Lamarck, 1816, *l.c.*, p. 227.

*L. hirta* Milne-Edwards, 1837, *Hist. Nat. Crust.*, ii., p. 188.

Extremely common along the whole western coast.

Family PORTUNIDAE.

NECTOCARCINUS TUBERCULOSUS Milne-Edwards, 1860.

*N. tuberculosus* Milne-Edwards, 1860, *Ann. Sci. Nat.*, ser. 4, xiv., p. 220.

Fairly common along the western coast.

Family GRAPSIDAE.

CYCLOGRAPsus AUDOUINII Milne-Edwards, 1837.

*C. audouinii* Milne-Edwards, 1837, *l.c.*, p. 78.

Very common in rock pools and between tide marks, seldom ascending more than a few yards above the wave-washed rocks. Specimens taken among weed were usually light fawn, tinged with orange, while those taken in bare pools or under basalt boulders were purple, mottled with light grey.

BRACHYNOTUS OCTODENTATUS (Milne-Edwards, 1832).

*Cyclograpsus octodentatus* Milne-Edwards, 1837, *l.c.*, p. 80.

*B. octodentatus* Hale, 1929, *l.c.*, p. 182.

Most common on western and southern coasts, ascending almost to the cliff top above McCoy Platform and the Drip. Commonly found in the fresh-water pools and tunnels of the springs on West Cape.

PLAGUSIA CHABRUS (Linnaeus, 1766).

*Cancer chabrus* Linnaeus, 1766, *Syst. Nat.*, ed. 10, p. 1044.

*P. chabrus* White, 1846, *Ann. Mag. Nat. Hist.*, xvii., p. 497.

Very common in the rock pools around the island, but not found above water level. Apparently largely vegetarian in diet, many cases were noted in which these crabs were seen to pluck and eat the filamentous green Algae. *P. chabrus* is a strong swimmer, swimming sideways by means of rapid strokes of the distal and penultimate joints of the legs, the legs all moving in unison.

Class ISOPODA.

Family GNATHIDAE.

Segmented and Praniza larvae were found attached to the fins and opercula of two specimens of *Bovichtus variegatus* (Rich.), which were found in a pool on Square Reef.

Family ANTHURIDAE.

MESANTHURA MACULATA (Haswell, 1881).

*Haliophasma maculata* Haswell, 1881, *Proc. Linn. Soc. N.S.W.*, v., p. 477.

*Mesanthura maculata* Hale, 1929, *l.c.*, p. 245.

One specimen was found on weed dredged in 3 fathoms at Dinghy Cove.

## Family SPHAEROMIDAE.

AMPHIROIDEA ELEGANS Baker, 1911.

*Amphoroidea elegans* Baker, 1911, Trans. Roy. Soc. S.A., xxv., p. 89.

EXOSPHAEROMA LAEVIS (Haswell, 1881).

*Sphaeroma laevis* Haswell, 1881, *l.c.*, p. 472.*Exosphaeroma laevis* Hale, 1929, *l.c.*, p. 276.

EXOSPHAEROMA sp.

CYMODOCEA ACULEATA Haswell, 1881.

*Cymodocea aculeata* Haswell, 1881, *l.c.*, p. 474.

## Family IDOTEIDAE.

EUIDOTEA BAKERI (Collinge, 1917).

*Paridotea bakeri* Collinge, 1917, J. Zool. Research, p. 112.*Euidotea bakeri* Hale, 1929, *l.c.*, p. 317.

PARIDOTEA MUNDA Hale, 1929.

*Paridotea munda* Hale, 1929, *l.c.*, p. 319.

## Family LIGIIDAE.

LIGIA AUSTRALIS Dana, 1853.

*Ligia australis* Dana, 1853, U.S. Explor. Exped., Crust., ii., p. 740.

## Family ARMADILLIDAE.

ARMADILLO (BUDDELUNDIA) ALBOMACULATUS Budde-Lunde, 1912.

*Armadillo (Buddelundia) albomaculatus* Budde-Lunde, 1912, Oniscidea in; Michaelsen and Hartmeyer, Die Fauna Sud-west Australiens, iv., p. 33.Indeterminate specimens of two species of Janiridae and one species each of *Oniscus* and Stenetridae were also collected.

## Class AMPHIPODA.

Except where otherwise stated, these species were obtained from rock pools and weed on the north coast of West Cape and in Dinghy Cove.

I am indebted to Mr. K. Sheard, of the Museum of South Australia, for his kindness in checking the identification of these specimens.

## Family LYSIANASSIDAE.

AMARYLLIS MACROPHTHALMA (Haswell, 1880).

*Amaryllis macrophthalma* Haswell, 1880, Proc. Linn. Soc. N.S.W., vi., p. 253, pl. viii., fig. 3.

## Family LEUCOTHOIDAE.

LEUCOTHOE SPINICARPA (Abildgaard, 1789).

*Gammarus spinicarpa* Abildgaard, 1789, in; Muller, Zool. Dan., ed. 3, iii., p. 66, pl. cxix., figs. 1-4.*Leucothoe spinicarpa* G. O. Sars, 1892, Crust. Norway, i., p. 283, pl. c.

## Family GAMMARIDAE.

ELASMOPUS SUBCARINATUS (Haswell, 1879).

*Megamoera subcarinata* Haswell, 1879, Proc. Linn. Soc. N.S.W., iv., p. 335.*Elasmopus subcarinatus* Stebbing, 1906, Das Tierreich, xxi., p. 441.

CERADOCUS RUBROMACULATUS (Stimpson, 1855).

*Gammarus rubromaculatus* Stimpson, 1855, Proc. Philad. Acad. Nat. Sci., vii., p. 394.

*Ceradocus rubromaculatus* Stebbing, 1906, *l.c.*, p. 430.

MAERA MASTERSII (Haswell, 1879).

*Megamoera mastersii* Haswell, 1879, *l.c.*, p. 265, pl. xxii., fig. 1.

*Maera mastersii* Stebbing, 1906, *l.c.*, p. 439.

PHERUSA sp.

Family DEXAMINIDAE.

PARADEXAMINE PACIFICA (Thomson, 1879).

*Dexamine pacifica* Thomson, 1879, Trans. N.Z. Inst., xi., p. 238.

*Paradexamine pacifica* Stebbing, 1906, *l.c.*, p. 363.

Family PONTOGENEIDAE,

PARAMOERA AUSTRINA (Bate, 1862).

*Atylus austrina* Bate, 1862, Cat. Amphipoda Brit. Mus., p. 137.

*Paramoera austrina* Stebbing, 1906, *l.c.*, p. 363.

Family TALITRIDAE.

HYALE GRANDICORNIS (Kroyer, 1845).

*Orchestia grandicornis* Kroyer, 1845, Natur. Tidsskr., ser. 2, i., p. 292.

*Hyale grandicornis* Stebbing, 1906, *l.c.*, p. 566.

TALORCHESTIA DIEMENENSIS (Haswell, 1879).

*Talorchestia diemenensis* Haswell, 1879, *l.c.*, p. 248.

This form was taken in brakish pools on McCoy Platform at about 25 feet above sea level.

PARORCHESTIA TENUIS (Dana, 1852).

*Orchestia tenuis* Dana, 1852, Proc. American Acad. arts sci., ii., p. 202.

*Parorchestia tenuis* Stebbing, 1906, *l.c.*, p. 557.

This form was found amongst moss and grass at the Drip, 90 feet above sea level.

Family AMPHITHOIDAE.

(?) AMPHITHOE FLINDERSI (Stebbing, 1888).

*Amphithoe flindersi* Stebbing, 1888, *l.c.*, p. 1120.

Family AORIDAE.

LEMBOS PHILACANTHUS (Stebbing, 1888).

*Autonoe philacantha* Stebbing, 1888, *l.c.*, p. 1082.

*Lembos philacanthus* Stebbing, 1906, *l.c.*, p. 598.

Family PODOCERIDAE.

ICILIUS OVALIS Dana, 1852.

*Icilius ovalis* Dana, 1852, *l.c.*, p. 220.

DULICHIA sp.

Family CAPRELLIDAE.

LIRIARCHUS PERPLEXUS Mayer, 1912.

*Liriarchus perplexus* Mayer, 1912, in Michaelsen and Hartmeyer—Die Fauna S.-W. Aust., iv. (1), p. 6.



19. *Arachnida*.

By J. A. TUBB.

Class PYCNOGONIDA.

Family AMMOTHEIDAE.

LECYTHORYNCHUS sp.

A juvenile specimen from a rock pool on the western coast of the Island. The ovigerous legs consist of two segments.

Family PALLENIDAE.

PALLENE LAEVIS Hoek, 1881.

*Pallene laevis* Hoek, 1881, Rep. Voy. Challenger, iii., p. 78, Pl. XI., figs. 8-12.

A large male, bearing two egg-masses, was dredged off West Cape, in 25 fathoms.

Family PHOXICHILIIDAE.

PHOXICHILIDIUM VIRESCENS Hodge, 1864.

*Phoxichilidium virescens* Hodge, 1864. Ann. Mag. Nat. Hist., ser. 3, xiii., p. 115. Pl. XIII., figs. 13-15.

One male from a rock pool on the western coast. The chelate mandibles are finely pointed and slightly incurved, their bases contiguous and slightly anterior to the oculiferous tubercle.

Class CHELONITHIDA.

Five species of Chelonithida were collected. Three appear to be new, and the range of two others is extended.

Family OLPIIDAE.

SOLINUS AUSTRALIENSIS Chamberlain, 1930.

*Solinus australiensis* Chamberlain, 1930, Ann. Mag. Nat. Hist., ser. 10, V., p. 597.

One specimen found beneath a basalt boulder near Seal Bay. Previously recorded from Barrington, N.S.W.

Family GARYPIDAE.

SYNSPHYRONUS PARADOXUS Chamberlain, 1930.

*Synsphyronus paradoxus* Chamberlain, 1930, loc. cit., p. 617.

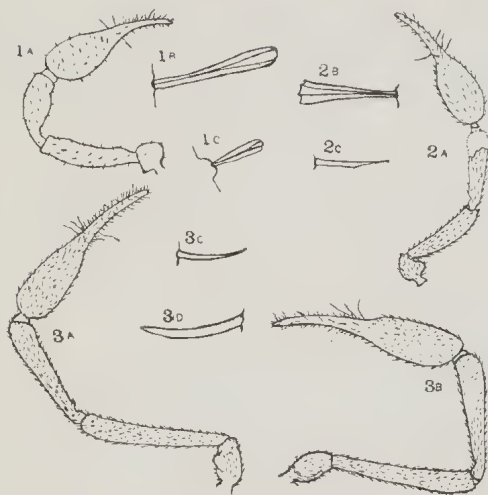
This is the species most commonly found on the Island. Many specimens were taken, and, towards the end of January, a female, with a number of white juveniles was found beneath a flat stone, in a pocket composed of silk and earth.

Genus **Maorigarypus**. Chamberlain, 1930.

MAORIGARYPUS VIRIDIS, sp. nov.

(Figs. 1, a-c.)

Female.—Light green, with black markings on the carapace and abdomen. Carapace typically garypoid, broader than long, anterior border emarginate, transverse furrows not observable.



FIGS. 1-3.

FIG. 1.—*Maorigarypus viridis* ♀. a. Left palp,  $\times 15$ . b. Seta of tergite,  $\times 325$ . c. Seta of palp,  $\times 325$ . FIG. 2.—*Ideocheilijer brevidigitatus* ♂. a. Right palp,  $\times 15$ . b. Seta of tergite,  $\times 325$ . c. Seta of palp,  $\times 325$ . FIG. 3.—*I. australis*. a. Left palp of ♀,  $\times 15$ . b. Right palp of ♂,  $\times 15$ . c. Seta of tergite of ♂,  $\times 325$ . d. Seta of palp of ♂,  $\times 325$ .

Eyes distinctly on anterior half of carapace.

Tergites I. and XI. entire, tergites II.-X. with median suture.

Surface finely shagreened, each tergite with 4 black spots, the posterior edge of each tergite with a deeper green band.

Tergites I.-VII. each with 4 setae, VIII.-X. each with 8 setae, XI. with 4 setae; all these setae are clavate.

Chelicerae typically garypoid, galea with two terminal branches, flagellum of three stout setae, the largest of which carries two lateral spines.

Palps stout, clothed with clavate setae. Trochanter rectangular, slightly longer than broad, one rounded prominence posteriorly. Femur pedicellate, as long as thorax, anterior face almost straight, posterior face convex. Tibia 2.2 times as long as broad, with a strongly bent pedicel. Chela pedicellate, pedicel constricted near hand, hand bilaterally swollen, broader than deep, fixed finger with 9 tactile setae, movable finger with one, vestitural setae clavate on hand, acute on fingers.

Fingers 1.2 times as long as hand, slightly curved. Total length.—2.8 mm. A single specimen found beneath a flat stone near Seal Bay.

## Family CHELIFERIDAE.

Genus **Ideochelifer**. Chamberlain, 1932.*IDEOCHELIFER BREVIDIGITATUS*, sp. nov.

(Figs. 2, a-c.)

Male.—Dark brown, carapace longer than broad, truncate anteriorly, transverse furrows distinct, posterior furrow closer to hind edge of carapace than to anterior furrow.

Tergites all with median clefts, surface of tergites and carapace granulate, posterior edge of tergites entire except for median cleft.

Chaetotaxy of tergites.—I., 16; II., 16; III., 16; IV., 18; V., 18; VI., 20; VII., 20; VIII., 20; IX., 16; X., 16; XI., 12. All these setae are broadened and denticulate at the tip.

Chelicerae project in front of the carapace, galea foliate at the tip, flagellum of three stout setae, the largest denticulate.

Palps stout, vestitural setae curved and acute. Trochanter pedicellate, broadly ovate. Femur stout, subpedicellate, 1.3 times as long as carapace, slightly longer than tibia. Tibia stout, pedicellate, 3 times as long as broad. Chela pedicellate, pedicel constricted near hand, hand swollen, little broader than deep, fingers sub-equal to hand.

Coxae IV. with coxal glands. Tarsi of fourth legs with simple subterminal setae, tarsi I. without terminal projections, all claws simple.

Total length.—2.7 mm.

One male found under a basalt boulder.

*IDEOCHELIFER AUSTRALIS*, sp. nov.

(Figs. 3, a-d.)

Female.—Body dark brown, legs and palps paler. Carapace longer than broad, transverse furrows distinct, distance between anterior furrow and posterior twice that between the posterior furrow and the hind edge of the carapace. Surface of carapace and tergites finely granulated.

Tergites all with median clefts, that of tergite II. very indistinct, posterior edges of tergites entire except for median cleft. posterolateral angles of tergites II. and III. are produced.

Chaetotaxy of tergites.—I., 12; II., 22; III., 22, IV., 22; V., 26; VI., 26; VII., 24; VIII., 24; IX., 24; X., 18; XI., 18.

Setae of tergites I.-X. are broadened and denticulate at the tip, setae of tergite XI. are curved and acute.

Chelicerae project in front of the carapace, galea foliate at the tip, flagellum of three stout setae, the largest denticulate.

Palps slender, vestitural setae curved and acute. Trochanter elongate oval, with a large rounded protuberance dorsally. Femur 1.2 times as long as the carapace, 1.1 times as long as the tibia. Tibia slender, 4.8 times as long as broad. Chela pedicellate, slender, 1.5 times as long as tibia, fingers 1.3 times as long as hand.

Tarsi IV. with simple subterminal setae, tarsi I. without terminal projections, all claws simple.

Total length—3.8 mm.

Male—Body almost black, legs and palps light brown.

Tarsi IV. with coxal glands. Otherwise similar to female.

Three adult and two immature specimens found near Seal Bay. This, like the foregoing species, is a rock dwelling form.

Types in the National Museum, Melbourne.

#### Class ACARI.

Parasitic acari occurred in very large numbers, but the Trombidoid mites, which formed a notable proportion of the rock frequenting arthropods, were more sporadic in occurrence.

#### Family ARGASIDAE.

*ORNITHODORUS TALAJE* var. *CAPENSIS* Neumann, 1901.

*Ornithodoros talaje* var. *capensis* Neumann, 1901, Mem. Soc. Zool. de France, XIV., p. 258.

Adults, nymphs and larvae were found in large numbers in the nests of the Little Penguin (*Eudyptula minor*).

Towards the middle of February, the viviparity of the species was demonstrated. Gravid females were seen on the shaded face of a basalt boulder, about 30 feet from the nearest penguin nest, and the emergence of the larvae was observed.

Larva:—

Body—length, 0.35 mm.; breadth, 0.26 mm.; broadly oval in contour, pale yellow, with numerous long setae (0.1 mm.) integument finely striated.

Capitulum—inserted ventrally, basis capituli hidden, palps and hypostome projecting in front. Palps slender, sub-equal to hypostome, furnished with a few setae, inner and terminal setae very short. Hypostome 0.16 mm. long.

Legs—robust, as long as the body, coxae contiguous, tarsi tapering abruptly, pedicel as long as the claws, pulvillus  $\frac{1}{4}$  as long as the claws.

This variety of *O. talaje* has previously been recorded from Cape Colony only.

## Family IXODIDAE.

IXODES PERCAVATUS Neumann, 1906.

*Ixodes percavatus* Neumann, 1906. Arch. Parasit. Paris, x., p. 200, figs. 4, 5.

Even more common than the previous species, in the nests of *Eudyptula minor*.

Male:—

Body—length, 3.4 mm.; breadth, 2.4 mm.; broadly oval, widest near the middle, tapering slightly anteriorly.

Scutum—polished, minutely punctate, dark reddish brown, a median prominence above the insertion of the basis capituli, marginal fold with numerous short setae.

Venter—anal grooves not closed behind, slightly convergent, terminating on the marginal fold. Genital aperture between coxae II. and III., spiracle almost circular, aperture eccentric.

Capitulum—slightly longer than broad, broadest at insertion of the palps, with a distinct posterior dorsal ridge. Basis capituli rectangular, palps slightly longer than hypostome, junction of articles II. and III. indistinct.

Legs—medium length, robust, furnished with stout setae, coxae and trochanters without processes, all tarsi distinctly humped, tarsus I. with a pit proximal to the terminal protuberance.

Female:—

Newly emerged—length, 2.7 mm.; breadth, 2.2 mm.

Engorged—length, 7.5 mm.; breadth, 6.2 mm.

Nymph (engorged):—

Body—length, 3.4 mm.; breadth, 2.4 mm. Scutum—relatively wider than in female. Capitulum—similar to female. Legs—relatively more robust than in female.

Larva (newly emerged):—

Body—length, 0.46 mm.; breadth, 0.43 mm. Scutum—broad, smoothly rounded, narrower posteriorly. Capitulum—cornua only slightly produced, palps and hypostome similar to female.

Legs—long, moderately robust, coxae and trochanters without spurs, tarsus I. with two tubercles and an intermediate depression, tarsi II. and III. indistinctly humped.

Egg—length, 0.34 mm.; breadth, 0.27 mm.

Found in the nests of *Eudyptula minor*, and later in a few burrows of the muttonbird (*Puffinus tenuirostris*), but only where the penguin nesting ground overlapped that of the muttonbird.



Most penguin nests contained large numbers of parasites. One nest, which may be regarded as typical, yielded over 200 specimens of *I. percaratus* and *O. talaje* var. *capensis*, in various stages of development.

Infestation of the hosts did not appear to be very heavy. Young and moulting penguins often carried several adult ticks and a few nymphs and larvae, but fully fledged birds were not observed to harbour adult parasites, the infestation being confined to nymphs and larvae.

Family HALARACHNIDAE.

Genus **Halarachne** Kramer, 1885.

HALARACHNE REFLEXA, sp. nov.

Female:—

Body—length, 5.8 mm.; breadth, 0.8 mm.; broadest at the middle of the scutum, "abdomen" more or less cylindrical.

Scutum:—elongate, narrowing abruptly in front, truncate posteriorly, surface finely shagreened, a median opaque area with paired lateral extensions between which are numerous more transparent spots on a brown background. Three pairs of setae occur on the scutum.

Venter—ventral plate ovoid, small, surface finely shagreened, three pairs of fine setae present. Vulva opens as a wide transverse slit just behind coxa IV. Spiracles comma-shaped, between legs III. and IV.

Anus—terminal, with three setae on a feebly chitinized ventral plate.

Capitulum—palps short and stout, article III. 1.5 times as long as article II., article II. subequal to article I. Vestitural setae fine, acute. Subterminal setae stout, forming a group of two or three. Chelicerae strong, retractile, basal segment broad, finger broadened at the tip, tip irregularly toothed.

Legs—short and stout, legs II. and III. more robust than legs I. and IV. Tarsi II. and III. narrowing abruptly to the claws; claws strong, pulvilli short. The chaetotaxy of the legs shows much individual variation.

Male:—

Body—length, 3.6 mm.; breadth, 0.7 mm.

Chelicerae—stout, retractile, curved and tapering, tip slightly recurved, rather blunt.

Genital aperture—between coxae IV.

In all other external features closely resembling the female.

This species is separable from *H. otariae* Steding by the shape of the scutum and the chelicerae.

The mites were found in the posterior nasal passages of the Tasmanian Sea Bear (*Arctocephalus tasmanicus* Lord and Scott). The infestations were very heavy in all the hosts examined.

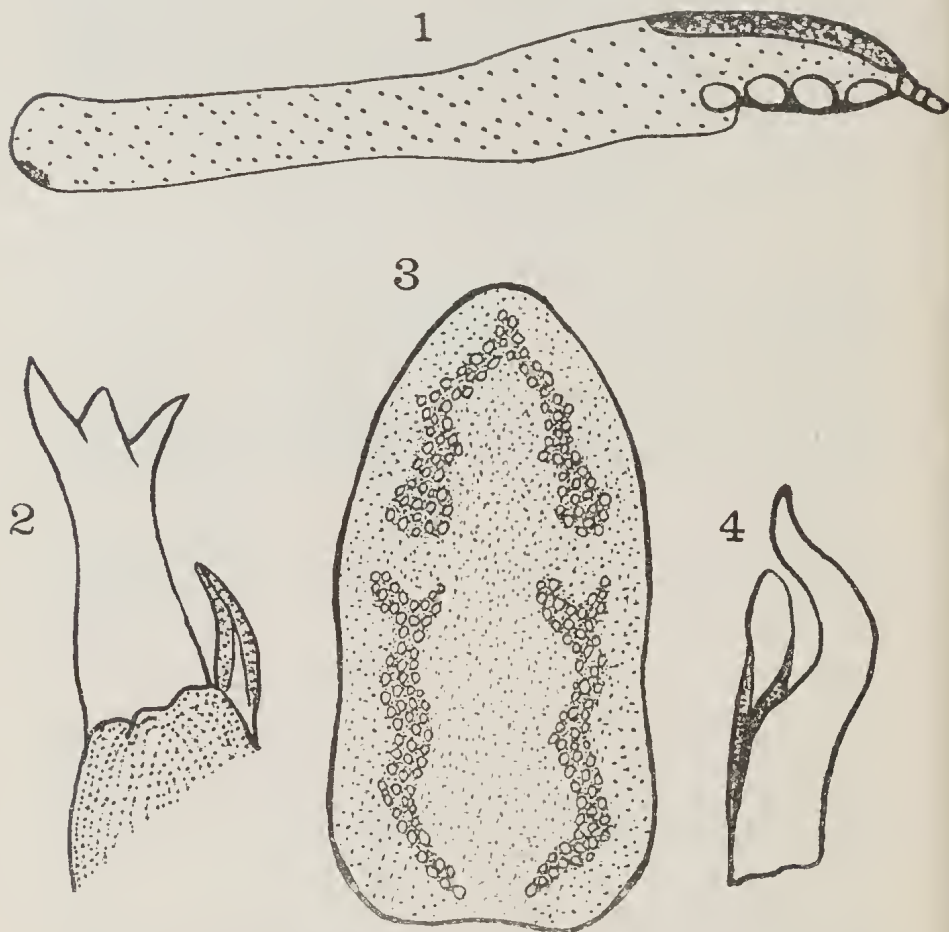


Fig. 1.—*Halarachne reflexa*, n. sp. 1. Lateral view,  $\times 12$ . 2. Chelicera of female,  $\times 220$ . 3. Scutum,  $\times 40$ . 4. Chelicera of male,  $\times 220$ .

The cephalothorax and legs of the parasite were buried in the mucous membrane, the long white "abdomen" protruding into the lumen of the nasal passage. The locus of infection was inflamed and swollen, and it was found impossible to dislodge the mites without causing extensive damage to the mucous membrane of the host.

Types in the National Museum, Melbourne.

Family DERMANYSSIDAE.

DERMANYSSUS sp.

Large numbers of these parasites were found in the nests of the muttonbird (*Puffinus tenuirostris*).

Family ERYTHRAEIDAE.

ERYTHRAEUS REGINA (Hirst, 1928).

*Leptus regina* Hirst, 1928. Ann. Mag. Nat. Hist., ser. 10, i., p. 569.

*Erythraeus regina* Womersley, 1934. Rec. S. Aust. Mus., v., p. 219.

With the exception of the parasitic forms, this is the most common mite on the Island. Almost every large stone, particularly near Seal Bay, yielded a large number of these acarines, adult nymphs and "pupae."

LEPTUS ORNATUS Womersley, 1934.

*Leptus ornatus* Womersley, 1934, loc. cit., p. 224.

This extremely beautiful species was found on the flowers and leaves of *Enchylaena tomentosa*, and its brilliant iridescence rendered it most conspicuous.

Family TROMBIDIIDAE.

MICROTROMEIDIUM KARRIENSIS Womersley, 1934.

*Microtrombidium karriensis* Womersley, 1934, loc. cit., p. 191.

CAENOTHROMBIUM NYNGANENSE (Hirst, 1928).

*Dinothrombium nynganense* Hirst, 1928, loc. cit., p. 556.

*Caenothrombium nynganense* Womersley, 1934, loc. cit., p. 205.

CAENOTHROMBIUM MINIATUM Womersley, 1934.

*Caenothrombium miniatum* Womersley, 1934, loc. cit., p. 206.

CAENOTHROMBIUM CRASSUM (Hirst, 1928).

*Dinothrombium crassum* Hirst, 1928, loc. cit., p. 567.

*Caenothrombium crassum* Womersley, 1934, loc. cit., p. 203.

These trombid mites were usually found in company with *Erythraeus regina*, but none of the species was common.

Family BDELLIDAE.

BISCURUS INTERMEDIUS Thor, 1928.

*Biscurus (Biscurus) intermedius* (Thor, 1928) Womersley, 1933. Trans. Roy. Soc. S. Aust., lvii., p. 104.

Two specimens of this active red mite were found on the cliffs above McCoy Platform.

20. *Tunicata, Ascidiacea.*

By J. A. TUBB.

## Family PYURIDAE.

PYURA AUSTRALIS (Quoy and Gaimard, 1834).

*Ascidia australis* Quoy and Gaimard, 1834, Voy. Astrolabe, Zool. iii., p. 614.*P. australis* Michaelsen, 1930, Die Fauna Sudwest-Australiens, v., p. 413.

One small specimen dredged in 25 fathoms off West Cape.

PYURA sp.

A single specimen related to *P. gibbosa* Heller, but differing in having foliate anal lobes, was found attached to the holdfast of Kelp.

## Family RHODOSOMATIDAE.

CORELLA JAPONICA Herdman, 1880.

*C. japonica* Herdman, 1880, Proc. Roy. Soc. Edinburgh, p. 472.

One small specimen found. This is a new record for Australian seas.

? CORELLA EUMYOTA Traustedt, 1881.

*C. eumyota* Traustedt, 1881, Vid. Medd. Nat. For. Kobenhavn, p. 273.

One juvenile specimen taken.

## Family STYELIDAE.

## Sub-family BOTRYLLINAE.

BOTRYLLOIDES LEACHI (Savigny, 1816).

For Synonymy see Michaelsen 1930; *loc. cit.*, p. 341.

Two small colonies found.

## Family CLAVELINIDAE.

## Sub-family POLYCITORINAE.

POLYCITOR CIRCES Michaelsen, 1930.

*P. circes* Michaelsen, 1930, *loc. cit.*, p. 495.Several colonies of *P. circes* Mch. were found exposed at low tide, and, although protected by overhanging rock ledges, were dry on the surface. In most cases they were uncovered for about two hours at each low tide. When the colonies were removed and placed in sea-water, the zooids rapidly expanded.

CYSTODITES DELLECHIAJE f. DURUS von Drasche, 1883.

For Synonymy see Michaelsen 1930, *loc. cit.*, p. 501.

One small colony found at Seal Bay.

DISTAPLIA MURRAYI (Herdman, 1886).

*Colella murrayi* Herdman, 1886. Rep. Voy. Challenger, xiv., p. 115.

One colony from 25 fathoms off West Cape.

DISTAPLIA sp.

A small colony of only three zooids, much contracted, found in a rock pool on Square Reef.

Family SYNOICIDAE.

AMAROUCIUM ALBIDUM Herdman, 1886.

*A. albidum* Herdman, 1886, *loc. cit.*, p. 234.

AMAROUCIUM EXILE Van Name, 1902.

*A. exile* Van Name, 1902, Trans. Conn. Acad. Sci., xi., p. 354.

The colonies referred to this species differ from the typical form in having slightly smaller zooids, 2.0–2.5 mm. long exclusive of the postabdomen, and the anal tongue is bilobed.

AMAROUCIUM VARIABILE Herdman, 1886.

*A. variabile* Herdman, 1886, *loc. cit.*, p. 216.

AMAROUCIUM GLOBOSUM Herdman, 1886.

*A. globosum* Herdman, 1886, *loc. cit.*, p. 219.

AMAROUCIUM CONSTRICTUM Sluiter, 1900.

*A. constrictum* Sluiter, 1900, Zool. Jahrb. Syst., xiii., p. 17.

APLIDIUM FALLAX Johnston, 1834.

*A. fallax* Johnston, 1834, Mag. Nat. Hist., ser. 1, vii., p. 15.

APLIDIUM sp.

PSAMMAPLIDIUM INCRUSTANS Herdman, 1899.

*Ps. incrustans* Herdman, 1899, Tunicata, Aust. Mus. Cat., 17, p. 87.

Family DIDEMNIDAE.

DIDEMNUM TONGA (Herdman, 1886).

*Leptoclinum tonga* Herdman, 1886, *loc. cit.*, p. 267.

*D. tonga* Hartmeyer, 1909, Bronn's Kl. und. Ord. des Thierreichs, iii., Suppl. Ib., p. 1451.



21. *Pisces*.

By J. A. TUBB.

## Family HETERODONTIDAE.

HETERODONTUS PHILIPPI (Bloch and Schneider, 1801).

*Squalus philippi* Bloch and Schneider, 1801, Syst. Ichth., p. 134.*Heterodontus philippi* McCoy, 1886, Prod. Zool. Vict., dec. xii., pl. 113.

## Family GALEIDAE.

MUSTELUS ANTARCTICUS Gunther, 1870.

*Mustelus antarcticus* Gunther, 1870, Brit. Mus. Cat. Fish, viii., p. 387.

## Family LAMNIDAE.

CARCHARODON CARCHARIAS (Linnaeus, 1758).

*Squalus carcharias* Linnaeus, 1758, Syst. Nat., ed. 10, p. 235.*Carcharodon carcharias* Garman, 1913, Mem. Mus. Comp. Zool., xxxvi., p. 32, pl. v., figs. 5-9.

## Family MYLIOBATIDAE.

MYLIOBATIS AUSTRALIS McLeay, 1881.

*Myliobatis australis* McLeay, 1881, Proc. Linn. Soc. N.S.W., vi., p. 380.

## Family ZEIDAE.

CYTTUS AUSTRALIS (Richardson, 1849).

*Capros australis* Richardson, 1849, Trans. Zool. Soc., iii., p. 72.*Cyttus australis* McCulloch, 1927, Fishes of N.S.W., p. 34.

## Family NOMEIDAE.

SERIOLELLA BRAMA (Gunther, 1860).

*Neptonemus brama* Gunther, 1860, Brit. Mus. Cat. Fish, ii., p. 390.*Seriocella brama* McCulloch, 1911, Sci. Repts. Endeavour Exped., p. 34.

## Family HYPOPLECTRODIDAE.

CAESIOPERCA RASOR (Richardson, 1839).

*Serranus rasor* Richardson, 1839, Proc. Zool. Soc., p. 95.*Caesioperca rasor* McCulloch, 1929-30, Mem. Aust. Mus., v., p. 155.

## Family SCORPIDAE.

SCORPIS GEORGIANUS Cuvier and Valenciennes, 1831.

*Scorpius georgianus* Cuvier and Valenciennes, 1831, Hist. Nat. Poiss., viii., p. 503.

## Family CHIRONEMIDAE.

CHIRONEMUS MARMORATUS Gunther, 1860.

*Chironemus marmoratus* Gunther, 1860, loc. cit., p. 26.

Family CORIDAE.

PSEUDOLABRUS TETRICUS (Richardson, 1840).

*Labrus tetricus* Richardson, 1840, Proc. Zool. Soc., p. 25.

*Pseudolabrus tetricus* McCulloch, 1913, Rec. Aust. Mus., ix., p. 377, pl. xix.

PSEUDOLABRUS FUCICOLA (Richardson, 1840).

*Labrus fucicola* Richardson, 1840, *loc. cit.*, p. 26.

*Pseudolabrus fucicola* McCulloch, 1929-30, *loc. cit.*, p. 309.

PSEUDOLABRUS MILES (Bloch and Schneider, 1801).

*Labrus miles* Bloch and Schneider, 1801, *loc. cit.*, p. 264.

*Pseudolabrus miles* McCulloch, 1929-30, *loc. cit.*, p. 309.

Family BOVICHTIDAE.

BOVICTUS VARIEGATUS (Richardson, 1846).

*Bovichthys variegatus* Richardson, 1846, Zool. Voy. Erebus and Terror, Fish., p. 56.

*Bovichtus variegatus* McCulloch, 1927, *loc. cit.*, p. 77.

Family ACINACIDAE.

THYRSITES ATUN (Euphrasen, 1791).

*Scomber atun* Euphrasen, 1791, Stockh. Vet. Akad. Nya. Hand., xii., p. 315.

*Thyrsites atun* McCulloch, 1921, Rec. Aust. Mus., xiii., p. 139.

Family BLENNIIDAE.

BLENNIUS TASMANIANUS Richardson, 1839.

*BleNNius tasmanianus* Richardson, 1839, *loc. cit.*, p. 99.

CLINUS PERSPICILLATUS Cuvier and Valenciennes, 1836.

*Clinus perspicillatus* Cuvier and Valenciennes, 1836, Hist. Nat. Poiss., xi., p. 372.

Family PLATYCEPHALIDAE.

PLATYCEPHALUS BASSENSIS Cuvier and Valenciennes, 1829.

*Platycephalus bassensis* Cuvier and Valenciennes, 1829, Hist. Nat. Poiss., iv., p. 247.

Family GOBIESOCIDAE.

DIPLOCREPIS CARDINALIS (Ramsay, 1882).

*Gobiesox cardinalis* Ramsay, 1882, Proc. Linn. Soc. N.S.W., vii., p. 148.

*Diplocrepis cardinalis* Waite, 1905, Rec. Aust. Mus., vi., p. 204.

Family ALETERIDAE.

CANTHERINES AYRAUDI (Quoy and Gaimard, 1824).

*Balistes ayraudi* Quoy and Gaimard, 1824, Voy. Uranie Physic., Zool., p. 216, pl. xlvii., fig. 2.

*Cantherines ayraudi* McCulloch, 1927, *loc. cit.*, p. 99.

## CANTHERINES GUNTHERI (McLeay, 1881).

*Monacanthus guntheri* McLeay, 1881, *loc. cit.*, p. 314.

*Cantherines guntheri* McCulloch, 1927, *loc. cit.*, p. 100.

## Family CHEILODACTYLIDAE.

## PSILOCRANIUM NIGRICANS (Richardson, 1850).

*Cheilodactylus nigricans* Richardson, 1850, *Proc. Zool. Soc.*, xviii., p. 26.

*Psilocranium nigricans* McCulloch, 1929-30, *loc. cit.*, p. 259.

Discounting the rock pool forms, the preceding list is made up of fish caught on hand lines, or observed. No equipment was taken with which an intensive survey of the fish fauna could be carried out, so that this report must necessarily be very incomplete.

Apart from the poorer types of fish, such as Kelpfish and Parrotfish, which were present in enormous numbers, many first class food fish were freely caught, particularly over the reef which extends eastward from Cape Frederic. *Seriola brama* and *Scorpius georgianus*, known locally as "Haddock" and "Sweep" respectively, were both common, and *Platycephalus bassensis* was taken from sandy areas off Dinghy Cove.

*Diplocrepis cardinalis* is a new record for Victorian waters.

The nomenclature adopted in this report is that used in McCulloch's Checklist of Fishes of Australia, *Mem. Aust. Mus.*, v., 1929-30.

22. *Reptilia*.

By J. A. TUBB.

Family SCINCIDAE.

EGERNIA WHITII (Lacépède, 1804).

*Scincus whitii* Lacépède, 1804, Ann. Mus. Nat. Paris, iv., p. 192.

*Egernia whitii* Boulenger, 1887, Brit. Mus. Cat. Lizards, iii., p. 135.

This species occurs in the following three distinct colour variations, peculiarly restricted in their distribution.

Form A.—Generally dark brown dorsally, scales olive brown with sparse black and white spots; head brown; eyelids edged with yellow. Restricted to a small area surrounding the Drip.

Form B.—Dark grey dorsally, with a median orange stripe and two lateral white stripes, sides mottled black, white and grey; head grey; scales and eyelids edged with white. Restricted to the talus slopes of Dinghy Cove.

Form C.—Similar to Form B, but with a white median stripe. Occurs all over the island.

23. *Aves.*

By FREDERIC WOOD JONES and J. A. TUBB.

**(A) Native species nesting on the Island.**

The nomenclature followed is that given in the Official Check List, R.A.O.U., Ed. 2, 1926.

## Family SPHENISCIDAE.

## EUDYPTULA MINOR (Forster, 1781).

*Aptenodytes minor* Forster, 1781, Comm. Gott., iii., p. 147.

The little Blue Penguins had their main breeding area on the western corner of the island, the birds reaching this area on the plateau by two well defined tracks, one ascending the talus slope at the head of Seal Bay, the other running over McCoy Platform and thence up the cliff to West Cape. Breeding birds were also nesting under the boulders of the talus slopes at Dinghy Cove, Seal Bay and McCoy Platform.

The birds assemble in Seal Bay at about sunset and all come ashore in a concerted rush. Scrambling on to the rocks at the water's edge, some time is spent shaking off the water and preening before commencing the laborious climb to the plateau. The ascent of the talus slope takes about an hour, and, by the time the first birds have reached the plateau, there is a continuous line of penguins, often four or five abreast, extending from the surf to the cliff top. Having attained the plateau, many birds still have a journey of half a mile before reaching their nesting burrows. At daybreak the parent birds start to descend the cliffs and remain at sea all day.

When the party first landed on the island the burrows contained fresh eggs or downy chicks and, by the end of the visit, almost all the young birds had taken to the water. The downy chicks leave their burrows at night and wander about whilst awaiting their parents, but they return to their burrows during the day.

After the chicks are ready to shift for themselves, the parent birds remain ashore for about a month while moulting. During the whole of this period they do not appear to feed, but they may be seen occasionally preening at the water's edge. During the moult, practically all the old plumage is shed at one time, and the moulting birds are much restricted in their activities and retiring in their habits.

## Family PROCELLARIIDAE.

## PUFFINUS TENUIROSTRIS (Temminck, 1835).

*Procellaria tenuirostris* Temminck, 1835, Pl. Col., livr. 99, pl. 587.

The Bass Strait Mutton Bird occupies two large rookeries on the island (see map), the northern breeding area being the largest. The birds come in on their homing flight at about sunset.



Large flocks were often seen feeding close to the island during the late afternoon. Eggs, both fresh and in an advanced stage of incubation, were found on our arrival at the island. The first downy chick was seen on January 15th and hatching continued until February 10th, by which time the more advanced chicks were showing signs of developing quill feathers. The burrows are often 3-4 feet in length and the nesting chambers, seldom more than a few inches below the surface, usually contain some dried twigs with an occasional admixture of feathers. The birds, even the downy chicks, are extremely pugnacious. Many eggs were found lying on the surface of the ground in the neighbourhood of the nesting burrows. No explanation of this state of affairs was discovered.

*PACHYPTILA TURTUR* (Kuhl, 1820).

*Procellaria turtur* Kuhl, 1820, Beitr. Zool., p. 143.

(The generic and specific designations of the Prions are at present determined on such insufficient grounds, that the nomenclature must be regarded as tentative.)

The Fairy Prions were first detected by the rays of electric torches as they came in to their retreats beneath the boulders on the talus slopes of Dinghy Cove. Their breeding season was evidently passed when we arrived on January 11th, but the birds returned after dark until the second week in February.

The measurements of birds secured on the island are as follows:—

Sex.				Wing.	Culmen, Length and Breadth.			Tarsus.
1	♂	..	..	174	23	x	11	31
2	♂	..	..	170	23	x	11	30
3	♂	..	..	170	23	x	10·5	31
4	♂	..	..	171	23	x	11	32
5	♂	..	..	175	24	x	11	32
6	♂	..	..	165	23	x	10·5	32
7	♀	..	..	166	23	x	10·5	32
8	♀	..	..	172	23	x	11	32
Average				170·3	23·1	x	10·8	31·5

Family PELECANOIDIDAE.

*PELECANOIDES URINATRIX* (Gmelin, 1789).

*Procellaria urinatrix* Gmelin, 1789, Syst. Nat., vol. i., pt. ii., p. 560.

Diving Petrels were seen or heard almost every night during the whole of our stay on the island. They came into Dinghy Cove after dark and usually made direct for the spaces beneath and between the boulders of the talus slope, but many birds were

found among the bracken at the cliff edge. The breeding season was evidently over at the time of our visit; but one dead, downy chick and one addled egg were found in the deep interstices beneath the boulders. The birds uttered a low-pitched, mewing call (key of F minor) and, unlike the Prions, are not confused by a beam of light.

The measurements of birds secured on the island are as follows:—

Sex.				Wing.	Culmen, Length and Breadth.	Tarsus.
1	♂	..	..	121	18.5 x 8	27
2	♂	..	..	125	16 x 8	27
3	♂	..	..	120	17 x 8	26
4	♀	..	..	122	17 x 7.5	25.5
5	♀	..	..	117	17 x 8	27
6	♀	..	..	122	15 x 8	26.5
7	♀	..	..	116	16 x 7.5	25
8	♀	..	..	122	17 x 8	26
9	♀	..	..	120	17 x 7.5	26.5
Average				120.5	16.7 x 7.8	26.2

The single egg measured 38 x 31.

#### Family CHARADRIIDAE.

##### CHARADRIUS RUFICAPILLUS Temminck, 1822.

*Charadrius ruficapillus* Temminck, 1822, Pl. col., 8, pl. 47, fig. 2.

Two adult Red-capped Dotterels were seen with a young bird evidently hatched on the island.

(A specimen was preserved for purposes of identification Nat. Mus. Coll.)

#### Family FALCONIDAE.

##### FALCO PEREGRINUS Tunstall, 1771.

*Falco peregrinus* Tunstall, 1771, Ornith. Brit., i.

A single pair of Peregrine Falcons was seen some time before the abandoned eyrie was discovered on a rock ledge in the cliff to the east of Cairn 2.

##### FALCO CENCHROIDES (Vigors and Horsfield, 1827).

*Falco cenchroides* Vigors and Horsfield, 1827, Trans. Linn. Soc., xv., p. 183.

A pair of Kestrels had their nest in a small cave high up the cliff to the north of Square Reef. The birds were generally to be seen about the cliffs though they rarely flew over the island plateau.

CIRCUS APPROXIMANS Peale, 1848.

*Circus approximans* Peale, 1848, U.S.A. Explor. Exped., viii., p. 64.

Some three or four pairs of Swamp Harriers are permanent residents on the island and on January 11th three nests were found containing fully-fledged young birds. The nests consist of an untidy heap of thistle and braeken with rabbit and mutton bird bones strewn around the edge. The Harrier preys largely upon young rabbits and, during the breeding season, takes toll of the mutton birds.

Family HIRUNDINIDAE.

HIRUNDO NEOXENA Gould, 1842.

*Hirundo neoxena* Gould, 1842, Birds of Aust., Pt. 9, ii., pl. 13.

Several nests of the Welcome Swallow were found on the walls of Guano Cave. One nest was apparently in process of reconstruction, and the birds were occasionally seen over the island plateau.

Family EPHTHIANURIDAE.

EPHTHIANURA ALBIFRONS (Jardine and Selby, 1828).

*Acanthiza albifrons* Jard. and Selby, 1928, Illus. Orn., ii., pl. 56.

White-fronted Chats were abundant among the thistles and braeken on the island plateau. No nests were found, but many immature birds were present. A specimen was preserved for identification (Nat. Mus. Coll.).

Family MOTACILLIDAE.

ANTHUS AUSTRALIS Vieillot, 1818.

*Anthus australis* Vieillot, 1818, Nouv. Dict. d'Hist. Nat., xxvi., p. 501.

Pipits were to be seen everywhere over the grassed area of the island. Three nests were found, two with eggs and one with newly-hatched chicks. A specimen was preserved for identification (Nat. Mus. Coll.).

**(B) Introduced species nesting on the Island.**

House sparrows and starlings were nesting in holes on the cliff face. Neither species is very abundant, and the birds were more often seen on the cliffs and shore platforms than on the top of the island.

**(C) Non-resident birds observed.**

The following marine species were noted in the vicinity of the island:—*Sula serratior* Gray; *Larus novae-hollandiae* Stephens; *Diomedea cauta* Gould. As occasional visitors to roek pools, *Demigretta sacra* (Gmelin) and *Notophox novae-hollandiae* (Lath.) were noted.

### Appendix.

*Stomach Contents of Tubinares Identified by H. M. Hale, South Australian Museum.*

Whole stomachs and samples of stomach contents of birds captured on their homcoming flight (when the food is more or less undigested) were preserved and forwarded to Mr. Hale. His report is as follows:—

*Puffinus tenuirostris*—

- (1) Stomach.—Packed with Mysids fairly well digested (mature form); about 50 Phoronomids; one *Megalopa*.
- (2) Stomach Contents.—Great numbers of Mysids (*Leptomysis* sp.).

*Pachyptila turtur*—

- (3) Stomach.—Mainly Mysids, apparently a different species from above (1 and 2); several Amphipods (probably Gammarids, but identification very uncertain). Five *Megalopas* of different species of crab than above (1).
- (4) Stomach Contents.—Thirteen Phoronomids; sixteen *Megalopas* of some large crab.

*Pelecanoides urinatrix*—

- (5) Stomach Contents.—Remains of four small fishes, possibly juvenile Carangids, which commonly congregate under Medusae at the period of year when bird was collected; a second species of fish is represented by a fragment of the head. Two Phoronomids of the same species as (4).

### Birds.

#### Explanation of Plates, XXV., XXVI.

- Plate XXV.—Fig. 1. *Eudyptula minor* (Forster). Birds ascending the track at Seal Bay. (Flashlight photo.)  
Fig. 2. *Puffinus tenuirostris* Temminck. Bird and egg in excavated burrow.
- Plate XXVI.—Fig. 1. *Pelecanoides urinatrix* Gmelin.



Penguins and Mutton Bird.







Petrel and Seals on Lady Julia Percy Island.



24. *Mammalia*.

By J. A. TUBB and C. W. BRAZENOR.

Order CETACEA.

Suborder MYSTACOCETI.

Family BALAENIDAE.

On two occasions large whales were seen off the southern end of the island. They were probably the Blue Whale, *Balaenoptera musculus* (Linnaeus, 1758).

Suborder ODONTOCETI.

Family DELPHINIDAE.

DELPHINUS DELPHIS Linnaeus, 1758.

*Delphinus delphis* Linnaeus, 1758, Syst. Nat., ed. 10, p. 77.

On February 2nd a school of about 24 dolphins was observed off the north coast of the island, travelling east. They were joined by seals from the island colonies who amicably escorted them along the coast.

Order CARNIVORA.

Suborder PINNIPEDIA.

Family OTARIIDAE.

ARCTOCEPHALUS TASMANICUS (Lord and Scott, 1925).

*Arctocephalus tasmanicus* Lord and Scott, 1925, Pap. and Proc. Roy. Soc. Tas., p. 187, pls. xvi.-xxi.

Between three and four thousand seals inhabit the caves and rocky beaches of Lady Julia Percy Island. Owing to the numerous shore platforms and beaches the western coast is most thickly populated, but Seal Bay on the south coast, and a cave and platform on the east coast of Cape Frederic, also support large colonies.

Aged bulls attain a length of about eight feet, and females are about five feet from nose to tail. A group of seals often shows great variation in colour, but this is almost entirely due to the degree of wetness of the fur. On emerging from the water they appear almost black, but the hue becomes lighter as the fur dries. When quite dry the adults are yellowish-brown, both above and below, though some females show lighter coloration, with patches of greyish-white on the throat, nape, and saddle. One abnormal specimen, pale grey on the back, and pure white below, was noted.

Skulls of aged males possess a well-developed sagittal crest. This is absent in all females and younger males. The post-orbital malar processes are large and, when viewed from a ventral aspect, curve well into the zygomatic area. They do not differ in any respect from the skulls of typical *A. tasmanicus*.

At the time of the Society's visit, upwards of a thousand pups, only a few weeks old, and about two feet long, were present. These were a uniform chocolate colour above and below. They sunned themselves on the beaches and played in the rock pools, but did not venture into open water.

It has been noted by sealers and others that fur seal communities are divided into groups. Each of the older bulls is reputed to possess a "harem" of females, which he allows no other bull to approach. This may be true during the breeding season, but at the time of our visit it was certainly not the case. Pups, females, and bulls of varying ages lay together on the rocks, and though fighting frequently took place, its usual cause was an attempt by one animal to usurp a particularly smooth and sunny place occupied by another. When fighting the animals stand breast to breast with noses pointing upwards. The teeth are used in a quick slashing blow, sometimes repeated, and the battle is accompanied by grunts and roars. Most often sheer weight appears to be the deciding factor.

It was possible, by exercising care, to approach quite close to the seals, but a sudden movement or a loud noise caused them to take to the water immediately. When disturbed, adult animals progress by using fore and hind limbs alternately in a clumsy lope, but when unhurried a modified quadrupedal action is sometimes used.

The animal performs its toilet with the pes, and the extremities of the toes can be folded inwards exposing the nails. These are used as a comb with a pushing action, the sole of the foot being uppermost.

The noise emanating from a seal colony is loud and incessant. The call of the bull is a hoarse, coughing roar; that of the cow is more highly pitched, and the bleating of the pups is reminiscent of domestic sheep. In calling, the nose is pointed in the air.

Breeding was over before the Society's visit, but local reports gave the pupping season as in early December; pups varied considerably in size so that it would appear to extend over several weeks. No case of twins was observed. Small pups were suckled on the shore, but larger pups were sometimes seen suckling in the water.

The acrobatics of the animals in the surf and in the fringe of kelp in more sheltered bays were amazing and entertaining. A favourite position, possibly when searching for food, was one in which the whole body except the hind flippers was vertically submerged. One seal was observed to remain in this position for three and a half minutes before coming up to breathe. The seals fed in the late afternoon. Excreta and debris on the beach suggested that barracouta formed the principal food, with parrot fish, squid and crabs as supplementary items.



The stomachs of a number of young and adult animals were examined for food contents and parasites. One adult contained a small number of parrot fish bones, the remainder being empty of food. Small pebbles, from  $\frac{1}{4}$  to  $\frac{1}{2}$  inch in diameter, were found near the pyloric end of the stomachs of the pups. Three animals contained 4, 7 and 8 respectively.

All adults were infested with large numbers of intestinal parasites. Round worms were found in the stomach, and tape worms in the caecum and large intestine. A parasitic mite was found in the posterior nasal passage of all seals including young pups, and a thread worm was discovered in fatty tissue underlying the skin of one animal.

Order RODENTIA.

Suborder DUPLICIDENTA.

Family LEPORIDAE.

Genus ORYCTOLAGUS.

ORYCTOLAGUS CUNICULUS (Linnaeus, 1758).

*Lepus cuniculus* Linnaeus, Syst. Nat., ed. 10, p. 57.

A pair of agouti coloured rabbits was liberated on the island in 1868. It is now heavily populated, and similar colour forms to those on the mainland occur. A large number of the grey form have small patches of white on the head and feet. The population no doubt fluctuates with good and bad seasons, but in December, 1935, 850 pairs were taken by trappers.

**Seals.**

**Explanation of Plate, XXVI.**

Plate XXVI.—Fig. 2. *Arctocephalus tasmanicus* Lord and Scott. Females and young on a shingle beach, Cape Frederic.



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Barrett, Sir J. W., K.B.E., C.M.G., M.D., M.S., 105 Collins-street, Melbourne, C.1	1910
Blackburn, Maurice, 2 Florence-street, Essendon, W.5	1936
Casey, Dermot A., c/o Melbourne Club, Collins-street, Melbourne, C.1	1932
Cherry, Prof. T. M., B.A., Ph.D., University, Carlton, N.3	1930
Clark, G. Lindesay, M.C., B.Sc., M.M.E., c/o Gold Mines of Australia Ltd., P.O. Box 856K, Melbourne, C.1	1931
Cudmore, F. A., 12 Valley View-road, East Malvern, S.E.6	1920
Davis, Captain John King, 35 Wills-street, Melbourne, C.1	1920



Dyason, E. C., B.Sc., B.M.E., 92 Queen-street, Melbourne, C.1	..	1913
Esserman, N. A., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3		1923
Gepp, Sir Herbert W., Box 1643, P.O., Melbourne	..	1926
Grimwade, W. Russell, B.Sc., 346 Flinders-lane, Melbourne, C.1	..	1912
Hartung, Prof. E. J., D.Sc., University, Carlton, N.3	..	1923
Jack, R. Lockhart, B.E., D.Sc., F.G.S., c/o Broken Hill Pty Ltd., 422 Little Collins-street, Melbourne, C.1		1931
Jones, Wood, Prof. F., D.Sc., M.B., B.S., M.R.C.S., L.R.C.P., F.R.S., F.Z.S., University, Carlton, N.3		1930
Jutson, J. T., B.Sc., LL.B., "Darlington," 9 Ivanhoe-parade, Ivanhoe, N.21		1902
Keble, R. A., National Museum, Melbourne, C.1	..	1911
Laby, Prof. T. H., M.A., Sc.D., F.R.S., University, Carlton, N.3	..	1915
Lewis, J. M., D.D.Sc., "Whitethorns," Boundary-road, Burwood, E.13		1921
Lyle, Prof. Sir Thos. R., M.A., D.Sc., F.R.S., Irving-road, Toorak, S.E.2		1889
MacCallum, Prof. Peter, M.C., M.A., M.Sc., M.B., Ch.B., D.P.H., University, Carlton, N.3		1925
Masson, Prof. Sir David Orme, K.B.E., M.A., D.Sc., F.R.S.E., F.R.S., 14 William-street, South Yarra, S.E.1		1887
Merfield, Z. A., F.R.A.S., 406 Toorak-road, Burwood, E.13	..	1923
Michell, J. H., M.A., F.R.S., 52 Prospect Hill-road, Camberwell, E.6		1900
Millen, Senator J. D., 90 William-street, Melbourne, C.1	..	1920
Miller, Leo F., "Moonga," Power-avenue, Malvern, S.E.4	..	1920
Miller, E. Studley, 396 Flinders-lane, Melbourne, C.1	..	1921
Newton, Sir Alan, M.B., M.S., F.R.C.S., 85 Spring-street, Melbourne, C.1		1931
Nicholas, Geo. R., 48 Lausell-road, Toorak, S.E.2	..	1934
Orr, Dr. R. Graeme, M.A., B.Ch., 621 Toorak-road, S.E.2	..	1935
Orr, Dr. W. F., 8 Collins-street, Melbourne, C.1	..	1932
Osborne, Prof. W. A., M.B., B.Ch., D.Sc., University, Carlton, N.3		1910
Patton, R. T., D.Sc., M.F., Hartley-avenue, Caulfield, E.8	..	1922
Penfold, Dr. W. J., M.B., Alfred Hospital, Commercial-road, Prahran, S.1		1923
Piesse, E. L., 43 Sackville-street, Kew, E.4	..	1921
Priestley, R. E., M.A., D.Sc., University, N.3	..	1935
Quayle, E. T., B.A., 27 Collins-street, Essendon, W.5	..	1920
Rae, F. J., B.A., B.Sc., B.Ag.Sc., Botanic Gardens, South Yarra, S.E.1		1927
Reid, J. S., 498 Punt-road, South Yarra, S.E.1	..	1924
Rigg, Gilbert, 20 Finch-street, Malvern, S.E.5	..	1931
Rivett, Sir David, M.A., D.Sc., Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2		1911
Rogers, J. Stanley, B.A., M.Sc., University, Carlton, N.3	..	1924
Sewell, Dr. S. V., 12 Collins-street, C.1	..	1936
Sexton, C. W. W., M.C.E., M.Inst.C.E., University, Carlton, N.3	..	1936
Shephard, John, "Norwood," South-road, Brighton Beach, S.5	..	1894
Singleton, F. A., M.Sc., University, Carlton, N.3	..	1917
Stillwell, F. L., D.Sc., 44 Elphin-grove, Hawthorn, E.2	..	1910
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Tiegs, O. W., D.Sc., University, Carlton, N.3	.. ..	1925
Vasey, G. H., B.C.E., University, Carlton, N.3	.. ..	1936
Wadham, Prof. S. M., M.A., Agr. Dip., University, Carlton, N.3	..	1932
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Young, Assoc. Prof. W. J., D.Sc., University, Carlton, N.3	..	1923

## COUNTRY MEMBERS.

Caddy, Dr. Arnold, "Chandpara," Tylden, Vic.	.. ..	1924
Caldwell, J. J., Geological Survey Office, Bendigo, Vic.	.. ..	1930
Cox, H. M. S., Wombat Park, Daylesford	.. ..	1931
Crawford, W., Gisborne, Vic.	.. ..	1920
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Hope, G. B., B.M.E., "Carrical," Hermitage-road, Newtown, Geelong, Vic.		1918
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Coulson, A. L., D.Sc., D.I.C., F.G.S., Geological Survey of India, 27 Chowringhee, Calcutta	1919
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Elford, H. S., B. E., c/o Tait Publishing Co., 39 Queen-street, Melbourne, C.1	1934
Fenner, C., D.Sc., Education Department, Flinders-street, Adelaide, S.A.	1913
Ferguson, W. H., 37 Brinsley-road, E. Camberwell, E.6 .. ..	1894
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Hardy, A. D., Forests Department, Melbourne, C.2 .. ..	1903
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Holmes, Mrs. S. C. A., M.Sc., Ph.D., c/o C. S. Holmes, 25 Eastbury- road, Kingston-on-Thames, Surrey	1930
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Lindsay, Miss Eder A., B.Agr.Sc., Agriculture School, University, N.3	1936
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MacDonald, B. E., "The Heights," 127 Banksia-street, Heidelberg, N.22	1920
McIver, Miss Euphemia, M.Sc., Gcology Dept., University, N.3	1936
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Moore, F. E., O.B.E., Chief Electrical Engineer's Branch, P.M.G.'s Department, Treasury Gardens, East Melbourne, C.2	1920
Morris, P. F., National Herbarium, South Yarra, S.E.1	1922
Newman, B. W., B.Sc., Meteorological Bureau, Sydney	1927
Nicholls, Miss A., B.Sc., 633 Inkerman-road, Caulfield, S.E.7	1929
Nye, E. E., College of Pharmacy, 360 Swanston-street, Melbourne, C.1	1932
Nye, Rev. Edward, B.A., Wesley College, St. Kilda-road, Prahran, S.1	1934
Oke, C., 34 Bourke-street, Melbourne, C.1	1922
Osborne, N., c/o Island Exploration Co., Daru, Papua	1930
Parr, W. J., 17 Bokhara-road, Caulfield, S.E.8	1927
Paterson, Miss Helen T., 16 Yarra-grove, Hawthorn, E.2	1933
Petersen, Miss K., B.Sc., 56 Berkeley-street, Hawthorn, E.2	1919
Prentice, H. J., B.Sc., 218 Esplanade West, Port Melbourne, S.C.1	1936
Pretty, R. B., M.Sc., Technical School, Wonthaggi, Vic.	1922
Proctor, Miss Eunice M., M.Sc., c/o Savings Bank, Heidelberg-road, Ivanhoe, N.21	1935
Raff, Miss J. W., M.Sc., F.R.E.S., University, Carlton, N.3	1910
Rayment, Tarlton, Bath-street, Sandringham, S.8	1929
Refshauge, Miss Lyly D., M.Sc., c/o Forests Commission	1935
Richardson, Sidney C., 2 Geelong-road, Footscray, W.11	1923
Rosenthal, Newman H., B.A., B.Sc., 10 Oulton-street, Caulfield, S.E.7	1921
Sayce, E. L., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3	1924
Scott, T. R., M.Sc., 7 Garden-street, Hawthorn, E.3	1934
Shaw, Dr. C. Gordon, 75 Clendon-road, Toorak, S.E.2	1931
Sherrard, Mrs. H. M., M.Sc., 43 Robertson-road, Centennial Park, N.S.W.	1918
Smith, J. A., 25 Collins-placc, Melbourne, C.1	1905
Stach, L. W., M.Sc., 78 Herbert-strect, Albert Park, S.C.6	1932
Stone, Mrs. Ilma, 24 Allandale-road, Eaglemont, N.22	1934
Sutherland, Miss Jean L., M.Sc., Presbyterian Girls School, Glen Ormond, Adelaide, S.A.	1934

Thomas, L. A., B.Sc., c/o Council for Scientific and Industrial Research, Stanthorpe, Queensland	1930
Traill, J. C., B.A., B.C.E., 630 St. Kilda-road, Melbourne, S.C.3 ..	1903
Trüdinger, W., 27 Gerald-street, Murrumbeena, S.E.9 .. ..	1918
Tubb, J. A., M.Sc., 91 Tooronga-road, Hawthorn .. ..	1936
Turner, A. W., D.Sc., D.V.Sc., Animal Health Research Laboratory, cr, Flemington-road and Park-street, Parkville, N.2	1925
Wilcock, A. A., B.Sc., Dip.Ed., 294 The Avenue, Parkville, N.2 ..	1934
Wilson, F. E., F.E.S., 22 Ferncroft-avenue, E. Malvern, S.E.5 ..	1921
Wilson, Major H. W., O.B.E., M.C., C. de G., B.Sc., 630 Inkerman-road, Caulfield, S.E.7	1923
Withers, R. B., B.Sc., Dip. Ed., University High School, Parkville, N.2	1935
Wood, E. J. F., M.Sc., B.A., Bacteriology Department, University, N.3	1935
Wood, Assoc. Prof. G. L., M.A., Litt. D., University, Carlton, N.3 ..	1933
Woodburn, Mrs. Fenton, 21 Bayview-crescent, Black Rock, S.9 ..	1930



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